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Kapteyn, A.; Alessie, R.J.M.; Lusardi, A.

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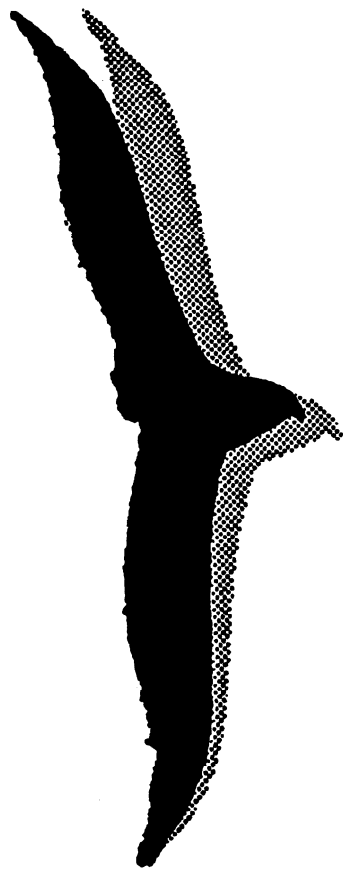
Explaining the wealth holdings of different cohorts:

Productivity growth and social security

Arie Kapteyn  
Rob Alessie  
Annamaria Lusardi

Research Memorandum 1999-38

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# EXPLAINING THE WEALTH HOLDINGS OF DIFFERENT COHORTS: PRODUCTIVITY GROWTH AND SOCIAL SECURITY

Arie Kapteyn\*  
Rob Alessie\*\*  
Annamaria Lusardi\*\*\*<sup>1</sup>

August 1999

## Abstract

It is well-known that individuals born in different periods of time (cohorts) exhibit different wealth accumulation paths. While previous studies have used cohort dummies to proxy for this fact, research in this area suffers from a serious identification problem, i.e., how to disentangle age, time, and cohort effects from a simple cross-section or a time series of cross-sections.

In this paper we propose to go beyond the simple use of cohort dummies to capture the differences in wealth accumulation across individuals born in different time periods. We introduce two indicators of the economic conditions under which households accumulate wealth. The first one represents productivity differences across cohorts: the aggregate level of GNP per capita when the head of the household entered the labor market. The second measure summarizes the changes in Social Security during the head of household's working life. The use of these indicators also gets around the identification problem.

We estimate the model using panel data from the Netherlands. This is a country whose historical conditions are ideal to study the effects of productivity growth and Social Security. The Netherlands experienced a steady growth after World War II. At the same time, it also built up a very extensive welfare system. Our empirical findings show that productivity growth goes a long way in explaining differences in income across cohorts. Productivity growth and Social Security can explain most, if not all, of the differences in wealth holdings of different cohorts. In comparison with the cohorts that lived without Social Security for a portion of their working life, the cohorts that had Social Security throughout their working life have less than half the accumulation rate of older cohorts.

JEL classification: D9 1, C23.

Keywords: Wealth Accumulation, Productivity Growth, Social Security.

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\* **Center**, Tilburg University, P.O. Box 90153, 5000 LE Tilburg, The Netherlands.

\*\* Free University Amsterdam, De Boelelaan 1105, 108 1 HV Amsterdam, The Netherlands, and Tinbergen Institute.

\*\*\* Harris School University of Chicago, 1155 E. 60<sup>th</sup> Street, Chicago, IL 60637. Phone: 773-702-5329, Fax: 773-702-0926. E-mail: [alusardi@midway.uchicago.edu](mailto:alusardi@midway.uchicago.edu).

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## 1. Introduction

There exists an important debate in the macroeconomic literature on the determinants of saving and wealth accumulation and how one can explain, for example, the sharp decline in saving that many developed countries witnessed during the 1980s. Some researchers have argued that it is simply the aging of the population that has caused the decline in saving. These might be called *age effects*. Others have argued that people coming of age in different times have different preferences. They argue, for example, that generations born after the Great Depression are less thrifty or less alert to risk than previous generations. An alternative view is that preferences may be identical across cohorts, but that the economic conditions of the past are very different from the present and that these differences are reflected in differences in wealth holdings across generations. Whether it is preferences or economic conditions, these considerations lead to the supposition of *cohort or generation effects*. Yet another group of researchers have instead argued that it is the capital gains in the stock market and the housing market that explain the decline in saving. These might be called *time effects*.<sup>1</sup> While all these theories have strengths and weaknesses, the critical issue is: how can we distinguish among age, cohort, and time effects?\*

In this paper, we tackle this issue by examining household wealth holdings over the life cycle. In particular, we study whether there are differences in the wealth profiles across cohorts and whether these differences can be attributed to economic factors such as productivity growth and changes in Social Security provisions.

It is well known that in cross-sectional data one cannot disentangle age and cohort effects in wealth. Shorrocks (1975) was the first to point out that productivity growth creates differences in household wealth holdings. Thus, solely on the basis of cross-sectional data one cannot study issues such as whether the elderly draw down wealth. A few authors have instead used time series of cross sections to study the behavior of wealth or saving.<sup>3</sup> They estimate a wealth or saving equation as a function of age dummies (or a polynomial in age) and cohort dummies. Additionally, one would like to include time dummies; however, this introduces an identification problem: calendar time is equal to year of birth (cohort) plus age.

Some authors, such as Attanasio (1993, 1998), simply acknowledge this identification problem and show

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<sup>1</sup> For a detailed discussion of these explanations, see Browning and Lusardi (1996).

<sup>2</sup> See Heckman and Robb (1985) for a detailed analysis of this issue.

<sup>3</sup> See Attanasio (1993), Deaton and Paxson (1994a), Venti and Wise (1993), and Jappelli (1995). See, also, Attanasio (1998) for a very thorough analysis of saving using time series of cross sections.

that one can only identify the age profile of the changes in saving and not the changes in wealth. Others impose restrictions on the time dummies. The leading approach is the one of Deaton and Paxson (1994b) in the context of a life cycle-permanent income model for consumption. They assume that the coefficients corresponding to the time dummies add up to zero and are orthogonal to a time trend. One possible justification for this assumption is that time effects are due to macro shocks and average out over time.

In this paper we address the identification problem in a different way. We make use of the restrictions stemming from a fairly standard version of the permanent income-life cycle hypothesis (PI-LCH).<sup>4</sup> More specifically, we consider the argument of other authors that productivity growth is an important factor in explaining differences across cohorts and model it in the context of the PI-LCH. Similarly, the model suggests that changes in Social Security (SS) provisions over the life time will affect savings in predictable ways. Rather than using cohort dummies, we model the cohort effects as a function of the productivity of different cohorts and of the extent of SS faced by different cohorts. Productivity of a cohort is proxied by the aggregate level of gross national product per capita when the head of the household entered the labor market (which we take to be age 22). SS is proxied by a measure which summarizes the changes in the SS system during the working life.

The advantages of using these measures rather than cohort dummies are several. Not only do we overcome the identification problem, but we can also determine more clearly the causes for the differences in income and wealth holdings across cohorts.<sup>5</sup> While many potential reasons have been proposed for explaining these differences, simple cohort dummies cannot distinguish, for example, between changes in economic circumstances and changes in preferences.

We estimate the model using panel data from the Netherlands. This is a country whose historical conditions are ideal to study the effects of productivity growth and SS. The Netherlands experienced a steady growth after World War II. At the same time, it also built up a very extensive welfare system! Both conditions can have important effects on household -wealth accumulation. In our empirical work, we first consider the effect of productivity growth on household income and find that it explains a substantial part of the differences in age-income profiles across cohorts. We then consider household wealth. Our empirical findings show that productivity growth and SS can explain most, if not all, of the differences in the wealth

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<sup>4</sup>See the discussion of this approach in Heckman and Robb (1985).

<sup>5</sup>The idea to relate cohort effects to observable cohort specific variables has been applied by several other authors, including Heckman and Robb (1985), Moffit (1987), Jonsson and Klevmarken (1978), and Klevmarken (1993).

<sup>6</sup>For detail, see van Ark, de Haan, and de Jong (1996).

accumulation of different cohorts.

To **summarize**, in this paper, we argue that past economic circumstances can explain the variation in paths of wealth accumulation across cohorts. In particular, our empirical work reinforces the findings of others, such as Shorrocks (1975) and Feldstein (1974), that productivity growth and Social Security are important determinants of wealth. In addition, we propose a parametrization of the cohort effect, that can get around the identification problem that is typically encountered in many studies. This strategy has wide applications and can be extended to other economic problems.

The paper is organized as follows: In Section 2, we consider the effect of productivity growth and **SS** on wealth. In Section 3, we describe the data set and examine the main features of wealth and income over the life cycle. In Sections 4 and 5, we describe the econometric specification and present our empirical results. In Section 6, we conclude and discuss further directions of research.

## 2. Theoretical framework

The model underlying our analysis is the simple PI-LCH. It serves as a framework of analysis and as a guide to construct our empirical variables. In this model, agents accumulate wealth to smooth consumption over the life cycle. In particular, we expect agents to continue to accumulate until retirement and then start drawing down assets. Under some restrictive assumptions (e.g. quadratic preferences, complete certainty, equality of the rate of time preference and the interest **rate**),<sup>7</sup> we can derive the closed-form solutions for both consumption and wealth. The expression for consumption is as follows:

$$c_t = Y_p = \left( \sum_{\tau=t}^L (1+r)^{t-\tau} \right)^{-1} \left( (1+r)A_{t-1} + \sum_{\tau=t}^L (1+r)^{t-\tau} y_{\tau} \right) \quad (1)$$

where  $c_t$  and  $y_t$  indicate consumption and non-capital income at age  $t$ ,  $r$  is the interest rate which is assumed to be fixed,  $A_{t-1}$  is non-human wealth in the previous period, and  $L$  is the length of life. Consumption is simply equal to permanent income, i.e., the present discounted value of lifetime resources. In this particular case, where there is complete certainty and the interest rate is equal to the discount rate, we obtain that consumption is simply constant over the life cycle. Wealth at age  $t$  is equal to accumulated saving:

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<sup>7</sup> Most results concerning the effect of productivity growth can be obtained while relaxing some of these assumptions. However, what is critical is that consumption remains a linear function of permanent income.

$$A_t = (1+r)^{t-1} \left[ (1+r)A_0 + \sum_{\tau=1}^t (1+r)^{1-\tau} (y_\tau - Y_p) \right] \quad (2)$$

Under reasonable assumptions about the behavior of income (rising income during the working years and a drop after retirement), the model gives the usual well-known prediction that wealth increases up to retirement and decreases thereafter.

If we introduce uncertainty into the model and interpret time effects as surprises in income, we can show that if at age  $t$  income exceeds its expectation, this will have a positive effect on wealth at age  $t$  (see Appendix A, equation (AS)). Thus, the model can illustrate in a straightforward way the existence of age and time effects in wealth accumulation. To illustrate cohort effects, we need a slightly more elaborate analysis.

## 2.1 Productivity growth

To examine the effect of productivity growth on wealth holdings of different cohorts, we compare wealth levels at age  $t$  of two different generations:  $c_1$  (the younger cohort) and  $c_2$  (the older cohort) in the presence of productivity growth. We consider a simple case of productivity growth by modeling the income of households  $h$  and  $i$  belonging to two different cohorts as follows:

$$\ln y_{th}^{c_1} - \ln y_{ti}^{c_2} = G_{c_1}^{c_2} + \omega_{thi} \quad (3)$$

where  $G_{c_1}^{c_2}$  is a constant specific to the cohorts  $c_1$  and  $c_2$  and  $\omega_{thi}$  represents all other sources of differences between the incomes of households  $h$  and  $i$ , e.g. due- to differences in education of the household head, the number of earners, etc. Importantly,  $\omega_{thi}$  is not a function of the cohorts to which these households belong. Thus (3) states that ***ceteris paribus*** at any age  $t$  the earnings of the two cohorts differ by a constant of proportionality, reflecting, for example, the higher salary at the start of the career of the younger cohort  $c_1$ .<sup>8</sup> If every generation starts with zero initial wealth, then (1) and (2) immediately imply that ***ceteris paribus*** the relative differences in consumption and wealth at age  $t$  between cohorts  $c_1$  and  $c_2$  are both equal to the relative difference in income. In other words, the parallel shift in income of cohort  $c_1$  relative to cohort  $c_2$

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<sup>8</sup> See Deaton (1995) for a similar assumption about the impact of productivity growth on the income process.

induces a parallel shift in the consumption profile, and accumulated wealth increases by the same magnitude. This also implies that while we have cohort effects in levels of wealth and consumption, the saving rate or the ratio of wealth to income (or consumption) will not display any cohort effects.’ While this model seems rather restrictive, it makes explicit the assumptions made in many of the previous works on consumption and wealth, and the justification behind the use of simple cohort dummies.

## 2.2 Social Security

While productivity growth is an important explanation for why wealth holdings differ across generations, in particular for those economies that experienced a high degree of economic growth, there are other economic events affecting the size of accumulation across different generations. In western societies the most important of these other factors is the introduction of an extensive SS system. In the Netherlands a universal SS system was instituted in 1957 and our data set includes households who were in the labor market well before the introduction of the system.”

SS wealth represents a very important component of total household wealth holdings. According to our calculations, total net worth for households whose head is 65-69 years old (in 1987) is approximately Dutch Guilders ( Dfl) 440,000, and more than Dfl 228,000 is accounted for by Social Security (medians are Dfl 354,200 and Dfl 246,700 respectively). Other age groups show similar results. Thus, half of total wealth of the elderly is accounted for by SS in the Netherlands.<sup>11</sup>

We have investigated the effect of the introduction and changes in Social Security when we allow for uncertainty about future income. Under the assumption that both the introduction of the SS system and subsequent changes are unanticipated (or equivalently, that all shocks are permanent), Appendix A investigates the effect of the introduction and changes in SS on consumption and wealth accumulation in the framework of the permanent income model. The unanticipated changes in SS creates a reduction in household (private) wealth. On the basis of the analysis in appendix A a proxy variable is formulated which captures the effect of the introduction and changes in SS on wealth holdings. This proxy variable is used in

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<sup>9</sup> See, also, Deaton and Paxson (1994b), Paxson (1996), and Jappelli (1995).

<sup>10</sup> The General Old Pension Act (AOW) of 1957 introduced Social Security to the entire Dutch population. Some pension provisions were present even before 1957, but they were restricted to some small groups of the population, mainly the very poor and civil servants. See, also, van Ark, de Haan, and de Jong (1996).

<sup>11</sup> For detail, see Alessie, Lusardi, and Kapteyn (1995).



the empirical part of this paper.

In Figures 1a and 1b, we provide a simple illustration of the effects generated by the introduction of SS. We consider three individuals. The first individual (who is a representative of the “old cohort”) lived in a time without SS. The second individual (a representative of the “middle aged cohort”) was 50 years old when the SS system was first introduced. The third individual (a representative of the “young cohort”) was 35 when SS was introduced. For simplicity, in these figures we assume that, after its introduction, the level of SS-benefits remains constant. The income profiles of the middle aged and young cohorts are different from the old one, since the former generations know that they will receive retirement benefits when they stop working. Due to the introduction of SS, savings by the middle aged as well as the young cohorts is shifted downwards (from age 50 and age 35 on). Wealth changes accordingly. In comparison with the old cohort, wealth is lower for the middle aged (young) cohort from age 50 (age 35) onwards. Note that the effect is not simply additive as in the case of productivity growth, but there is an interaction between age and cohort effects in the accumulation of wealth. The decrease in wealth is not just a parallel shift, but changes with the age of the head of the household.

This is another important aspect of modeling cohort effects using the predictions of the theory. This derivation **highlights** that it is very restrictive to use cohort dummies to model cohort effects, since it is easy to envisage cases where the effect is not simply additive, but, as in the case of SS, there are interactions between cohort and age effects. In addition, cohort dummies can be rather difficult to interpret when as in these examples, some past economic conditions (productivity growth) lead to an increase in wealth across cohorts, while others (SS) to a decrease. For policy considerations, it may be very important to disentangle those effects in the data.

While the basic framework here is the PI-LCH, qualitatively the findings concerning the effects of productivity growth and SS on consumption and savings will also hold under different models, such as a precautionary saving model or a model with uncertain life time or a bequest motive. The effect of these extensions is to induce extra motives to save during the working life and to reduce decumulation after retirement in comparison with the current model, but decumulation may still be expected beyond a certain age (see, e.g., Hurd (1989, 1998), and Browning and Lusardi (1996)). Apart from that, productivity growth and SS have effects on wealth accumulation in the same direction as in the current model. We use the model simply as a framework for the analysis and as a guide to devise the variables to be used in the empirical estimation.

Another simplification in the model introduced above is the absence of labor supply responses, as utility is assumed to depend on consumption only. In a model with both consumption and leisure in the utility

function in a non-separable way, one expects an effect of the introduction of SS on the timing of retirement and hence on the savings rate during one's working life: the introduction of SS increases lifetime resources for the older cohorts (the expected present discounted value of their SS benefits is greater than the value of the extra payroll tax). This increase in lifetime resources may conceivably be consumed in the form of more leisure, e.g., through early retirement. This in itself increases the need to save for retirement and hence may offset the depressing effect of SS on savings.<sup>12</sup>

### **3. The data**

#### **3.1 Description of the Socio-Economic Panel**

The empirical work is based on the Netherlands Socio-Economic Panel (SEP), conducted by Statistics Netherlands. It is a micro data set representative of the total population, excluding those living in special institutions like nursing homes. The first survey was conducted in April 1984. The same households were interviewed again in October 1984 and then twice a year (in April and October) until 1989. In the years since 1990, all the information was collected in one interview, which was held in May of each year. In the October interview, information was collected on socioeconomic characteristics: demographics, income, labor market participation and hours of work. In the April interview, information was collected on socio-economic characteristics as in the October interview, but, rather than collecting data about income, from 1987 onwards, information was collected on assets and liabilities. In this paper, we use income data from 1984 until 1990, and wealth data from 1987 until 1991.<sup>13</sup>

An evaluation of the quality of the SEP data and a comparison with macro statistics or other micro data sets is reported in Alessie, Lusardi and Aldershof (1997). We can briefly summarize their findings as follows: the data on some major components of wealth, such as housing, mortgage debt, and checking accounts are well reported in the SEP and compare reasonably well with aggregate statistics. However, some other components, in particular stocks, bonds, and savings accounts seem under-reported in the SEP, and the level of measurement error may also change over time. This problem is typical of wealth surveys and can be found

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<sup>12</sup> See, for example, Diamond and Hausman (1984).

<sup>13</sup> All money values have been deflated using the Consumer Price Index and are expressed in 1987 Dutch guilders. The exchange rate between Dutch Guilders and US dollars was 2.03 in 1987 (2.03 Dfl=1\$).

in other similar data sets.<sup>14</sup>

We have deleted from the sample those cases with missing or incomplete responses in the assets and liabilities components and in the demographics.<sup>15</sup> We have also excluded the self-employed from the sample. The quality of the wealth data is very poor for these households, and additionally, wealth data for the self-employed are not available after 1989. Due to these selections, we find that both low and high wealth households have a tendency to drop out of the sample. We will take selectivity into account in our empirical work.

### 3.2 Household income

In this section we report some basic facts about income. In particular, we first examine whether there is evidence of productivity growth in the raw data. In order to construct some simple statistics for households in the same year of birth (cohorts), we have re-arranged the data as follows: We have defined eleven cohorts by choosing a 5 year-of-birth interval and have considered all households, from the ones born in 1911-1915<sup>16</sup> (they are 72-76 years old in 1987) until the ones who represent the last wave of the baby-boom generation (they are born in 1961-65 and are 22-26 years old in 1987).<sup>17</sup>

Over the years, there has been a steady decrease in the average family size. Younger cohorts have substantially reduced the size of their family relative to older generations. This change in family size is composed of several effects. Not only has the number of children decreased, but there has also been a decrease in the number of married couples. The percentage of married couples went from 70.4 in 1984 to 61.6 in 1991. These facts are not inconsequential for income and for wealth accumulation, and we will take them into account in the empirical work.

In Figures 2a and 2b, we plot mean and median non-capital income from 1984 to 1990 for each cohort.

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<sup>14</sup> See Davies (1979), Avery, Elliehausen, and Kennickell (1988), Avery and Kennickell (1991), and Hurst, Luoh, and Stafford (1998).

<sup>15</sup> In some cases, missing data on assets and liabilities could be imputed. See Camphuis (1993) for more details on the data imputation and Alessie, Lusardi and Aldershof (1997) for a description of the criteria used to calculate total net worth.

<sup>16</sup> Whenever we speak of the age of a household we mean the age of the head of the household.

<sup>17</sup> For a detailed explanation of this methodology, see Browning, Deaton and Irish (1985) and Attanasio (1993, 1998). Note that we have deleted the households whose head is younger than 22 (in 1987) to exclude the persons still in school, and the households whose head is older than 76 (in 1987) to partly avoid the strong correlation between mortality and wealth holdings.

For clarity, the graphs only indicate the average year when the head of the household was born (for example, “38” refers to heads of households born between 1936 and 1940). The vertical difference between lines measures the “cohort-time” effect. The difference along the same line measures the “age-time” effect?

The figures show that there are both cohort-time and age-time effects in income. As mentioned before, productivity growth in the economy could induce generation effects in wages and income. Indeed, non-capital income has been increasing strongly across cohorts up to the households born in 1928 or earlier. The biggest cohort-time effect is between the cohort born between 1936-1940 and the one born between 1931-1935.<sup>19</sup> The age-time effect is also large. In particular, the young and middle-age households experience a sizable increase in non-capital income as they move along in their career.

The effects across generations could simply reflect the changes in the labor force participation of Dutch households. For example, female labor force participation has been increasing over time, and the fraction of families with two earners has increased considerably. The SEP data show that there has been a substantial increase in the labor force participation among young couples and there is a strong cohort-time effect for couples whose head is 50 years or younger. In Figure 3, we report mean non-capital income per income recipient (results are similar for median non-capital income per income recipient). As expected, the increase in labor market participation accounts for part of the cohort-time and the age-time effect. However, these effects are still present in the data per earner; thus, there also appears to be evidence for productivity growth in individual income.

### 3.3 Financial and total net worth

We use two measures of household net worth: financial net worth and total net worth. The first measure is obtained by summing the amounts reported in checking accounts, saving certificates, bonds, stocks, options and other such securities, cars, claims against private persons and subtracting the total amount of debt (which is composed of loans and credit, installment credit, other debt and **loans**).<sup>20</sup> Total net worth is obtained by adding to **financial** net worth the value of the house and other real estate, the home-owner’s insurance policy,

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<sup>18</sup> We use this terminology to emphasize that it is not possible to disentangle age **from** cohort and time effects in these figures. See also below.

<sup>19</sup> Historically, wage controls were implemented in the 1950s, but these controls were lifted in the early 1960s and wages grew substantially in that period. Growth came to a halt in the 1970s with two severe recessions.

<sup>20</sup> The reason why we include durables, such as cars, in this definition of wealth is because we cannot distinguish between car loans and other debts.

and subtracting the mortgage debt. We consider these two measures of wealth to study in some detail the importance and role of housing equity.

In Table 1 we report the distribution of financial and total net worth in 1987 and 1991. A few facts can be noticed from this table. First, there is substantial dispersion in household wealth holdings, with about 9% of the households having a negative net worth. Second, the fact that means are well below the medians suggests that the distributions of financial and total net worth are skewed to the right. Third, both financial and total net worth have increased substantially in the five-year period. Note that not only means and medians increased, but also standard deviations went up, indicating that the distribution of wealth is more dispersed in 1991 than in 1987. Fourth, it is clear by looking at differences between financial and total net worth that housing equity plays an important role in the portfolio and wealth accumulation of many Dutch households.

We have also looked at wealth holdings across types of households. Differences are sizable. While **single-**person households report median total net worth of Dfl 5,500 in 1987, married couples report 5 times as much (the median is Dfl 28,900).<sup>21</sup> Furthermore, the presence of children has a strong negative effect on wealth. We also find remarkable differences in wealth accumulation across education groups. Households whose head has a college education report median total net worth of **Dfl 37,000**, while median total net worth of households whose head only has an elementary education is **Dfl 7,860**.<sup>22</sup>

In Figures 4a and 4b we plot mean and median total net worth from 1987 to 1991 for each cohort. The figures show that there are substantial cohort-time effects as well as age-time effects in total net worth. Within the same cohort, both mean financial and total net worth are steadily increasing over time. This is particularly true for the young cohorts, but even for some elderly mean net worth continues to increase over time. Most of the wealth accumulation is done by the middle age cohorts (households born between 1931 and 1945). The increase in mean total net worth over the **5-year** period is as big as **Dfl 40,000**. The graphs for total net worth confirm the findings of the means, but further highlight the increase in total net worth for the middle age cohorts. The fact that mean and median total net worth increase for most cohorts in a “parallel” way suggests that time effects may also be important. This effect may be due, for example, to common macro shocks, changes in housing prices or stock market **prices**.<sup>23</sup>

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<sup>21</sup> For comparison, see Smith (1994), who reports differences in wealth holdings across marital status for US households.

<sup>22</sup> Similar findings are reported in Bernheim and Scholz (1993), and Attanasio (1994) using US data.

<sup>23</sup> There is another potential cause for the existence of these time effects. It is possible that the amount of measurement error, and particularly under-reporting of wealth, is decreasing over time. As we noted before, some assets are under-reported, particularly in the first year, and households may become more accurate in their reports as they repeat answering the same questions over time. In the econometric specification below we will take this effect into account.

Looking across cohorts, we find that there are also remarkable differences in wealth accumulation. The biggest cohort-time effects are experienced by the households born before and during World War II, between 1931 and 1945. These effects are present both in the mean and in the median. It is noteworthy that generations born after 1946 do not show as sharp an increase in wealth as older generations. Time effects could also be relevant in affecting the size and magnitude of the differences in wealth accumulation across cohorts.

Given the differences between financial net worth and total net worth reported in Table 1, it is useful to investigate housing equity separately. Housing is an important asset in the household portfolio. As Figure 5 indicates, home-ownership has been increasing over time for the young and middle-age cohorts. Across cohorts, the increase in home-ownership has been particularly high for the households born between 1931-1945. The cohorts born after 1950 exhibit very little cohort-time effects. Not only has home-ownership increased across the older cohorts, but the prices of homes have also risen considerably between 1984 and 1991. While important, home-ownership is, however, not solely responsible for the existence of cohort-time effects in total net worth. In Figures 6a and 6b we report financial wealth and show that strong cohort-time effects are still present in the mean and median of this more restrictive measure of wealth.

We have also investigated the effects of capital gains on bonds and stocks on wealth accumulation. The stock market index went from 62.2 in 1980 to 191.4 in 1991 • an increase of more than 300%. From 1987 to 1991, the increase in the stock market index was 50%. While relevant, this increase affects only a limited number of households; the percentage of stockholders was only 6.1% in 1987 and 8.8% in 1991. We have examined the data excluding capital gains on housing and stocks and found that the “cohort-time” effects in wealth remain sizable. It is therefore unlikely that cohort-time effects can be explained simply by a change in housing prices or by other time effects, while productivity growth and other economic circumstances remain potentially important explanations for the pattern of wealth holdings across cohorts.

#### **4. Econometric specification for income**

In the econometric analysis, we take an unbalanced panel and consider household income between 1984 and 1989 and household wealth between 1987 and 1991. Our first objective is to check whether productivity growth is an important phenomenon and whether we can detect it in household income even after controlling

for many explanatory variables. Our aim is not to construct a full model of household income dynamics.<sup>24</sup> Therefore, we consider the following fairly simple model to describe household income:

$$\ln(z_{th}) = \zeta_0 + \sum_{i=1}^5 \zeta_i age_{th}^i + \sum_{\tau=1985}^{1989} \gamma_{\tau} TD_{\tau} + \sum_{i=2}^6 \Delta_i LD_{ith} + \sum_{i=2}^5 \phi_i SD_{ith} + X'_{th} \beta + u_h + \varepsilon_{th} \quad (4)$$

where  $t$  = time index,  $t=1984, \dots, 1989$ ;

$h$  = household index;

$z_{th}$  = non-capital income of household  $h$  in year  $t$ ;

$age_{th}$  = age of the head of the household in year  $t$ ;

$TD_{\tau}$  = time dummies, equal to one if  $\tau=t$ , and zero otherwise;

$LD_{ith}$  = learning dummies (to be explained below);

$SD_{ith}$  = selectivity dummies (to be explained below);

$X_{th}$  = vector of demographic and socioeconomic characteristics;

$u_h$  = individual (random) effect;

$\varepsilon_{th}$  = random i.i.d. error term.

In equation (4), we specify a flexible relationship between income and age by considering a fifth order age polynomial. We have included in the vector of demographic and socio-economic characteristics,  $X_{th}$ , the following variables: number of adults in the households, number of children in different age groups (6 or younger, between 7 and 12, between 13 and 17, 18 years or older), the gender of the head of the household, and dummy variables indicating the education level of the head of the household (primary, lower secondary, higher secondary, and university education).

The individual-specific effect,  $u_h$ , in equation (4) represents unobserved heterogeneity. We want to allow for the possibility that the individual effects are correlated with other right-hand-side variables. It is well-known after the work of Mundlak (1978) that this can be done in two equivalent ways. One possibility is to assume that individual effects are fixed and estimate them as individual parameters. The second possibility, which we choose, amounts to modeling the individual effect by making it dependent on household specific means of all time varying right-hand-side variables. Furthermore, we want to allow for cohort effects by making the individual effects dependent on the year of birth of the household head. Let  $W_{th}$  be the matrix of

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<sup>24</sup> A more realistic specification would allow for various interactions between age, cohort, and time effects, as, for example, in MaCurdy and Mroz (1995) and Weiss and Lillard (1979). However, as Heckman and Robb (1985) point out, the inclusion of interaction terms aggravates the identification problem.

all time varying explanatory variables on the right hand side of (4), plus a column of ones. That is,  $W_{th}$  includes  $X_{th}$ , the time dummies, learning dummies, and selectivity dummies. Define  $\bar{W}_h \equiv 1/T \sum_t W_{th}$  i.e., the time average of  $W_{th}$ . We then model the individual effects as follows:<sup>25</sup>

$$u_h = \bar{W}_h \gamma + \sum_{c=1912}^{1965} \delta_c CD_{ch} + \theta_h \quad (5)$$

where  $CD_{c,}$  = cohort dummies;  $c$  = year of birth cohort index,  $c=1912, \dots, 1965$ . We assume that the individual effects  $\theta_h$  are random and uncorrelated with the explanatory variables. The inclusion of fixed individual effects has the additional advantage that it takes care of all selectivity that is dependent on time invariant factors.<sup>26</sup>

To allow for the possibility that there are additional attrition effects we have also included the “selectivity” dummies ( $SD_{it}$ ) in the equation. These dummies are defined as follows:  $SD_{it} = 1$  if the household participates in year  $t$  and participates at least one more time in the survey after period  $t$ . The dummies pick up the possibility that respondents who participate at least one more year are different from those who drop out.

To allow for the possibility of learning effects, “learning” dummies ( $LD_{it}$ ) have been included. The learning dummies are constructed as follows: we have defined dummies for the number of times households participate in the survey (since the sample period for the income equation covers 6 periods, the maximum number of times a household participates is equal to 6). Our motivation is that as households participate in the survey they become either better or worse (for example more lazy) in answering the questionnaire.<sup>27</sup>

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<sup>25</sup> Without loss of generality we can omit from  $\bar{W}_h$  the mean values of the variables  $age_{th}^1, \dots, age_{th}^5$ , since in a balanced panel the means are linearly related to cohort specific variables.

<sup>26</sup> See Verbeek and Nijman (1992).

<sup>27</sup> The idea behind this can be formalized as follows:

Let  $z_{th}^*$  be the true value and  $z_{th}$  the measured value of the dependent variable. Suppose that the following relationship between the measured and true value of the variable  $y$  exists:

$$\frac{z_{th}^*}{z_{th}} = \left( \alpha_0 + \alpha_1 e^{-\alpha_2 t} \right) e^{u_{th}} \quad \square^a$$

with  $u_{th}$  a white noise error term, and where  $t=1$  represents the first interview in which a respondent participates. The interpretation of this equation would be that the parameter  $\alpha_2$  (which is assumed to be positive) determines how quickly a respondent learns, i.e. how quickly the bias in the response converges to  $\alpha_0$ , which represents the amount of systematic



Notice that in a balanced panel,  $LD_{ith}$  is just a set of time dummies. In other words, one cannot distinguish between learning effects and, for example, macroeconomic shocks. However, we work with an unbalanced panel. A similar comment can be made regarding the selectivity dummies.

If we insert (5) into (4), the resulting equation explains incomes on the basis of time, cohort, and age effects. Since birth year plus age is equal to calendar year, these three variables satisfy an exact linear relationship, which makes it impossible to disentangle time, cohort, and age effects.

#### 4.1 Identification of cohort, age, and time effects

The most general characterization of the identification problem is obtained by representing age effects by age dummies (one for each age), cohort effects by cohort dummies (one for each birth year), and time effects by time dummies (one for each time period). To avoid the trivial identification problem due to the fact that each group of dummies adds up to one, we drop the first dummy of each group. Let us collect all remaining dummy variables and the vector corresponding to the constant term in a matrix  $D$  as follows:

$$D = \begin{bmatrix} TD & CD & AD & \mathbf{1} \end{bmatrix} \quad n, \quad (6)$$

$$\mathbf{T-1} \quad \mathbf{C-1} \quad \mathbf{T+C-2} \quad \mathbf{1}$$

where  $n$  is the total number of observations, the  $n \times (T-1)$ -matrix  $TD$  contains the time dummies, the

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under- or over-reporting in the long run. The parameter  $a$ , determines whether initially responses are higher or lower than the long run response, and by how much. Equation (a) can be rewritten in logarithmic terms as:

$$\ln(z_{ith}) = \ln(z_{ith}^*) + \ln(\alpha_0 + \alpha_1 e^{-\alpha_2 t}) + u_{ith} \quad (b)$$

Equation (b) displays a slightly non-standard measurement error problem. The measurement error consists of two parts: a random part and a systematic part. The random part,  $u_{ith}$ , is a white noise error with expectation zero and constant variance. The systematic part displays the “learning” effect. If one assumes that the parameters  $\alpha_0$ ,  $a$ , and  $\alpha_2$  do not depend on household characteristics, then equation (b) can be rewritten as follows:

$$\ln(z_{ith}) = \ln(z_{ith}^*) + \sum_{i=1}^T \Delta_i LD_{ith} + u_{ith} \quad (c)$$

where  $LD_{ith}=1$  if at time  $t$  the household takes part in the panel for the  $i$ -th time  
0 otherwise

$$\Delta_i = \ln(\alpha_0 + \alpha_1 \exp(-\alpha_2 t))$$

$n \times (C - 1)$  -matrix  $CD$  contains the cohort dummies, the  $n \times (T + C - 2)$  -matrix  $AD$  contains the age dummies, and the  $(n \times 1)$  -vector  $\mathbf{1}$  consists of unit-elements exclusively. All dummy variables have been arranged in increasing order. That is, in  $TD$  the first column refers to the second time period, the second column refers to the third time period, etc. Similarly, the first column of  $CD$  refers to the second oldest cohort, the second column refers to the third cohort, and so on. Let us partition the associated parameter vector  $\boldsymbol{\varphi}$  as:

$$\boldsymbol{\varphi}' = \begin{pmatrix} \boldsymbol{\varphi}_t' & \boldsymbol{\varphi}_c' & \boldsymbol{\varphi}_a' & \boldsymbol{\varphi}_0 \end{pmatrix} \quad \begin{matrix} \mathbf{T}-\mathbf{1} & \mathbf{C}-\mathbf{1} & T+C-2 & \mathbf{1} \end{matrix} \quad (7)$$

Define:

$$\lambda_t = \begin{pmatrix} 1 \\ 2 \\ \vdots \\ \mathbf{T}-\mathbf{1} \end{pmatrix} \quad \lambda_c = \begin{pmatrix} 1 \\ 2 \\ \vdots \\ \mathbf{C}-\mathbf{1} \end{pmatrix} = \begin{pmatrix} 1 \\ \tilde{\lambda}_c \end{pmatrix} \quad \lambda_a = \begin{pmatrix} 1 \\ 2 \\ \vdots \\ T+C-2 \end{pmatrix} \quad (8)$$

It is easy to verify that the columns of  $D$  satisfy the following linear relationship:

$$-TD\lambda_t + CD\lambda_c + AD\lambda_a - \mathbf{1}(C-1) = \mathbf{0} \quad (9)$$

Relation (9) reflects the fact that birth-year plus age equals calendar year.

Partition the matrix  $CD$  and the vector  $\boldsymbol{\varphi}_c$  as follows:

$$CD \equiv [CD_1, \tilde{CD}] \quad \boldsymbol{\varphi}_c' \equiv (\boldsymbol{\varphi}_{c1}, \tilde{\boldsymbol{\varphi}}_c') \quad (10)$$

where  $CD_1$  is an  $n$ -vector and  $\boldsymbol{\varphi}_{c1}$  is a scalar. Furthermore, define:

$$\tilde{D} \equiv [TD, \tilde{CD}, AD, \mathbf{1}], \quad (11)$$

i.e.,  $\tilde{D}$  is the matrix of dummy variables obtained by omitting the first time dummy, the first two cohort dummies, and the first age dummy. Clearly  $\tilde{D}$  spans the same space as  $D$ , so we can write:

$$D\boldsymbol{\varphi} = \tilde{D}\boldsymbol{\Gamma}\boldsymbol{\varphi} \equiv \tilde{D}\boldsymbol{\pi}, \quad (12)$$

where  $\boldsymbol{\pi}$  is a vector of “reduced form parameters” and  $\boldsymbol{\Gamma}$  a known  $(2T + 2C - 4) \times (2T + 2C - 3)$ -

matrix. We partition  $\pi$  in conformity with  $\tilde{D}$  as follows:

$$\pi' = \begin{pmatrix} \pi'_t & \pi'_c & \pi'_a & \pi_0 \end{pmatrix} \quad \begin{matrix} \mathbf{T-1} & \mathbf{c-2} & \mathbf{T+C-2} & \mathbf{1} \end{matrix} \quad (13)$$

The relation between the reduced form parameters  $\pi$  and the structural parameters  $\varphi$  is as follows:

$$\pi_t = \varphi_t + \varphi_{cl}\lambda_t \quad (14)$$

$$\pi_c = \tilde{\varphi}_c - \varphi_{cl}\tilde{\lambda}_c \quad (15)$$

$$\pi_a = \varphi_a - \varphi_{cl}\lambda_a \quad (16)$$

$$\pi_0 = \varphi_0 + \varphi_{cl}(C-1). \quad (17)$$

This can be verified by checking that  $D\varphi = \tilde{D}\pi$ .<sup>28</sup>

The expressions for the reduced form parameters fully characterize the identification of the structural parameters. We can solve the structural parameters from (14)-(16) as follows:

$$\varphi_t = \pi_t - \varphi_{cl}\lambda_t \quad (18)$$

$$\tilde{\varphi}_c = \pi_c + \varphi_{cl}\tilde{\lambda}_c \quad (19)$$

$$\varphi_a = \pi_a + \varphi_{cl}\lambda_a \quad (20)$$

Consider the difference between two adjacent elements of  $\varphi_t, \tilde{\varphi}_c, \varphi_a$ :

$$\varphi_{ti} - \varphi_{t,i-1} = \pi_{ti} - \pi_{t,i-1} - \varphi_{cl} \quad i=2,\dots,T-1 \quad (21)$$

$$\tilde{\varphi}_{ci} - \tilde{\varphi}_{c,i-1} = \pi_{ci} - \pi_{c,i-1} + \varphi_{cl} \quad i=2,\dots,C-1 \quad (22)$$

$$\varphi_{ai} - \varphi_{a,i-1} = \pi_{ai} - \pi_{a,i-1} + \varphi_{cl} \quad i=2,\dots,C+T-2 \quad (23)$$

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<sup>28</sup> Use (9) to solve for  $\varphi$ :  $CD_1 = -\tilde{C}\tilde{D}\tilde{\lambda}_c + TD\lambda_t - AD\lambda_a + (C-1)\mathbf{1}$ . This allows us to write:

$$\begin{aligned} D\varphi &= TD\varphi_t + CD_1\varphi_{cl} + \tilde{C}\tilde{D}\tilde{\varphi}_c + AD\varphi_a + \mathbf{1} \cdot \varphi_0 \\ &= TD[\varphi_t + \varphi_{cl}\lambda_t] + \tilde{C}\tilde{D}[\tilde{\varphi}_c - \varphi_{cl}\tilde{\lambda}_c] + AD[\varphi_a - \varphi_{cl}\lambda_a] + \mathbf{1} \bullet [\text{cP}, -\text{Cp}, -(c-1)] \\ &= \tilde{D}\pi \end{aligned}$$

As  $\varphi_{cI}$  is unknown, this formulation makes clear that one cannot identify first differences of parameters. In particular, this makes it impossible to determine whether age profiles are upward or downward sloping.<sup>29</sup> The same result has been obtained earlier by, for example, Heckman and Robb (1985), Deaton and Paxson (1994a), Attanasio (1998). The reason to give a derivation, is that it suggests a straightforward solution.

## 4.2 Modeling of cohort effects

There is a different way of addressing the identification problem, namely by imposing restrictions which follow from economic theory. The analysis in Section 2 suggested that cohort effects in income and wealth may be due to productivity growth and changes in SS. In general terms, we impose the following structure on the cohort effects:

$$\varphi_c = G\psi \quad (24)$$

where  $G$  is a  $(C-1) \times k$ -matrix of observables (with full column rank) and  $\psi$  a  $(k \times 1)$ -vector of unknown parameters. This relation imposes restrictions on the cohort effects and thereby serves to identify all parameters as long as  $k \leq C-2$ , where  $k$  is the rank of  $G$ .

If  $k$  is strictly less than  $C-2$  and if the matrix  $G$  does not contain the variable ‘year of birth’, (24) provides overidentifying restrictions of the form  $CD\varphi_c = CDG\psi$ . These can be tested using a Wald test. The alternative hypothesis in the Wald test is a model in which no restrictions are imposed on the vector  $\varphi_c$ . This is a non-identified model and can be estimated by arbitrary deleting one cohort, or time, or age dummy, as explained in section 4.1. An intuitively appealing way of performing the Wald test is to include both  $CD^*$  and  $CDG$  in the matrix of regressors where the matrix  $CD^*$  is obtained from the matrix  $\tilde{CD}$  (see equation 10) by arbitrarily deleting  $k$  columns (cohort dummies) and to test whether the parameters corresponding with  $CD^*$  are zero.

Acceptance of the null of no (remaining) cohort effects also avoids the potential problem that the errors in the equation would exhibit a cohort effect. Such a structure would be different from the assumed error component structure where there are only individual effects and a white noise error term, and hence would

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<sup>29</sup> Conceivably, a researcher may be willing to put bounds on  $\varphi_{cI}$ , e.g.  $\varphi_{cI} \geq 0$  implying a cohort effect for cohort 2 to be at least as large as for cohort 1. In that case it follows from (21) that  $\tilde{\varphi}_{it} - \tilde{\varphi}_{t,i-1} \geq \pi_{it} - \pi_{t,i-1}$ .

invalidate all standard errors and statistical inference drawn on the basis of them. In fact the Wald-test proposed here is closely related to the F-test proposed by Moulton and Randolph (1989) to detect group effects in the equation errors.

Equation (24) can easily be generalized to the case where additive modeling of cohort effects constitutes a misspecification in the sense that interactions with other variables (e.g. age) have been incorrectly left out. Suppose that rather than a term  $CDG\psi$ , the true effect on the left hand side variable of the equation would have been  $\zeta Z$ , where  $Z$  is some observable variable, which cannot be written as an exact linear combination of the cohort dummies, and  $\zeta$  is an unknown parameter. One can still test this null by including both  $CD$  and  $Z$  in the matrix of regressors and testing whether the parameters corresponding with  $CD$  are zero.

### 4.3 Empirical results for income

Before implementing the approach suggested above, we first follow Deaton and Paxson (1994a, 1994b) and assume that the year dummies are orthogonal to a time trend and sum to zero. We have tested the hypothesis that the coefficients corresponding to the learning dummies are equal to zero. This hypothesis cannot be rejected ( $\chi^2(5)=6.91, p=0.23$ ). The estimation results also suggest that attrition does not lead to biases in the coefficients of the first moments of the conditional distribution of log non-capital income; the selectivity dummies are not significant ( $\chi^2(4)=3.04, p=0.55$ ). We have also tested the joint significance of the learning and selectivity dummies. The test statistics do not indicate rejection of the null that the coefficients corresponding to these dummy variables are equal to zero ( $\chi^2(9)=1.75, p=0.23$ ). We have thus decided to remove the learning and selectivity dummies from the income equation.<sup>30</sup> The estimation results are reported in Table 2.

Even though not reported, the demographic variables play an important role in the income equation. We find that the individual effects are correlated with demographics. The individual effect is, for example, strongly positively correlated with the education level of the head of the household. This is a very plausible result: the individual effect picks up some unobserved (time invariant) characteristics like talent and ability and not surprisingly such characteristics are positively related to education. Many demographic variables enter the income equation significantly. For example, non-capital income increases by more than 20% whenever the number of adults increases by one. The presence of young children has a depressing effect on income. The joint significance of the education and demographic variables (and their means) is very strong

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<sup>30</sup> Note, however, that we include these variables in the wealth equation.

$(\chi^2(17)=4089.57)$ .

As Figure 2a already suggested, we find that the cohort dummies are jointly significant ( $\chi^2(54)=218.17$ ,  $p=0$ ). The polynomial in age is also significant and the parameter estimates indicate a hump-shaped age-income profile. However, these results are purely an effect of the identifying assumption. With other identifying assumptions, other patterns could be found.

#### 4.4 An alternative way of accounting for productivity growth

We take the explanation that productivity growth is the reason for the existence of cohort effects in income one step further. We have created a variable that can measure this effect directly, i.e. the value of real gross national product per capita (RGNPC) when the head of the household was 22. In this way, we capture the state of the economy around the time the head of the household entered the labor market. In terms of equation (24), the matrix  $G$  has one column containing the values of RGNPC for all year-of-birth cohorts. In Figure 7, we plot the behavior of RGNPC for every year-of-birth cohort. RGNPC increases rather steadily over time, but it experiences variation particularly around the time of recessions.

The alternative specification in which we remove all cohort dummies and add the RGNPC variable (in logs) is reported in column 2 of Table 2. As before, we have excluded learning and selectivity dummies since they are not statistically significant. The coefficient of aggregate income when the head of household was 22 is positive (0.358) and statistically significant (s.e. 0.078). This result gives support to the hypothesis that productivity growth is an important explanatory variable for household income.

We find that the coefficients of the demographic variables (and their means) are very similar to the other specification. Furthermore, we find that the coefficients of the time dummies are highly significant. Note that in this case we do not need to make any identifying assumptions concerning the time dummies.

It could be the case that the RGNPC variable, while accounting for the growth in the economy over the past, is also picking up the business cycle conditions when entering the job markets. To verify the sensitivity of results to our chosen specification, we have also considered an average of GNPC per capita from age 20 to age 24. Results are virtually unchanged and we work hereafter simply with the RGNPC variable.<sup>31</sup>

We have also considered the cross-sectional specification for income, which does not include any cohort effects (specification 3 in Table 2). In Figure 8, we plot the age-earnings profile resulting from that

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<sup>31</sup> We have also considered different measures of aggregate production such as real disposable income per capita, and results do not change. These results are available from the authors upon request.

specification together with the specification using RGNPC. The cross-section profile differs a lot from the profile that accounts for cohort effects. In particular, it reaches a top rather early, and it declines sharply afterwards with age.

Since in our specification we do not have to make any assumptions on the time dummies, we can also test whether the restriction on these dummies is supported by the data. As already apparent in Table 2, the hypothesis that the time dummies are orthogonal to a time trend is rejected at the 1% level ( $\chi^2(1) = 7.57$ )

As suggested before, we have also tested the specification using RGNPC against a specification with a full set of cohort dummies.<sup>32</sup> The Wald test indicates rejection at the 5% level, but not at the 1% level of significance.<sup>33</sup> As one can see from Table 2, in comparison with the specification without the RGNPC variable the  $\chi^2$ -statistic for the joint significance of the cohort dummies falls by 21.1. Our simple proxy for productivity growth is obviously an important explanatory variable. On the other hand, the cohort variables remain jointly significant indicating that household incomes are affected by more than just productivity differences at the start of one's working life. Some of these have already been mentioned, such as increases in participation rates and decreases in household sizes, or the existence of potential interactions of age, time, and cohort effects. It may also be the case that differences in the sizes of various cohorts affects their economic fortunes (see, e.g., Easterlin, Schaeffer, and Macunovich (1993)). Since the emphasis of the paper is on wealth and not on income, we abstain from any further analysis of the cohort effects in income.

### 5. Econometric specification for wealth

Despite the relatively simple income process postulated in the previous section, the implied equation for household wealth is already quite complicated, particularly if one wants to properly account for demographics. Some of these complications are sketched in Appendix B. As a first approximation, the initial specification for wealth will be taken to be similar to that for income. There are two main differences. The **first** difference is trivial; since the data for wealth cover 1987-1991 rather than 1984-1989, some of the time indices have a different range. The second difference has to do with the left hand side variable:  $z_{it}$  is now

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<sup>32</sup> As mentioned before, we have to remove one cohort dummy to perform the Wald test.

<sup>33</sup> One could argue that the alternative model is maximally 'non-parametric.' For example, one concern is that this test artificially inflates the degrees of freedom. We can impose more structure by using a more parsimonious (nonlinear) cohort function using a fifth order polynomial in years of birth. If we test the specification using RGNPC against this more heavily parameterized model, the Wald test still indicates rejection at the **5%-level** but not at the 1% level. Thus, the test results presented in the main text are not simply driven by an "overparameterization" of the alternative hypothesis.

wealth. As mentioned before, a sizable proportion of households hold zero or negative net worth (approximately 9 percent of the sample). This precludes the use of a log-transformation. On the other hand, the wide dispersion of the net worth distribution, with a small number of households holding huge amounts of wealth, makes a log-like transformation desirable. Hence we use the hyperbolic sine as a transformation of net worth:

$$h(z_{th}) = \ln (z_{th} + \sqrt{z_{th}^2 + 1}) \quad (25)$$

where  $z_{th}$  is net worth of household  $h$  at time  $t$ . The hyperbolic sine is anti-symmetric, i.e.,  $h(z)=-h(-z)$ . The function approximates the logs for positive values of net worth that are not too small (and minus the log for negative values of net worth) and hence shares the property that it down weighs extreme observations.

As was the case with income, we estimate a random effects model as implied by equations (4) and (5) with the inclusion of household specific means of time varying explanatory variables. In the case of wealth, learning dummies and selectivity dummies affect the estimates of the time dummies. Therefore, we always include both the selectivity and the learning dummies. We model the profile of wealth over the life cycle with a fifth order polynomial in age.

As with income, cohort effects will be modeled as a function of productivity growth. But now we also include a variable that represents changes in SS over the years of one's working life. By assuming that individuals in society take every change in SS as permanent and that preferences are quadratic, we can derive exactly how the time path of SS provisions should influence the wealth accumulation of different cohorts (see appendix A and, in particular, equation (A. 19)). The variable thus constructed is denoted as  $DSS$ . We test whether productivity growth and SS are sufficient to capture all cohort effects in the data. Finally we perform various tests of our specification by considering various interactions and testing whether the associated coefficients are zero.

## 5.1 Empirical results for wealth accumulation

Table 3 contains the estimation results for both total and financial net worth. Demographic variables turn out to be very significant in the estimation of wealth. Households whose head is highly educated (higher secondary education and above) have higher wealth than households whose head has a low education. Additionally, the presence of small children has a depressing effect on wealth.

We find evidence for a displacement effect of SS on wealth. The variable measuring the cohort effect of



SS (*MDSS*)<sup>34</sup> is negative and statistically significant. *DSS*, which measures the interactions between cohort and age effects is not statistically significant. In other words, changes in SS between 1987 and 1991 (captured by the variable *DSS*) did not affect wealth accumulation, while changes in SS in the past (captured by *MDSS*) did. A test of this model against a model with a full set of cohort dummies and *DSS*<sup>35</sup> does not lead to rejection ( $p=0.720$ ).<sup>36</sup>

We have also considered the extent of cohort effects in the other measure of wealth, financial net worth. The coefficients of *DSS* and *MDSS* are both negative and jointly statistically significant ( $\chi^2(2) = 9.09$ ,  $p=0.01$ ). The test on the validity of this model against a model with a full set of cohort dummies again does not lead to rejection ( $p=0.911$ ). We note that although RGNPC has the expected sign in all cases, it is not significantly different from zero.

Figures 9a and 9b present the age-wealth profiles (using the hyperbolic sine) for different generations using the estimates reported in Table 3.<sup>37</sup> For all generations considered in these figures, the age function tends to start sloping downward around retirement (for the 1911 generation) or shortly after retirement (for the younger generations), as would be predicted by various versions of the PI-LCH. Furthermore, due to the effect of (the introduction of) SS the amount of decumulation after retirement of the 1935, and 1946 generations is smaller than that of the 1911 generation, as would be predicted by the model presented in Section 2. To verify whether decumulation of wealth becomes significantly negative, Figures 10a and 10b present the relative change in wealth from year to year (with 95% confidence bands around them) for the 1911 generation. The point estimates confirm that there is decumulation in both financial wealth and net worth, which starts around the time of retirement. However, the confidence bands are large and decumulation is not statistically significant for that cohort.

To assess the impact of SS, we can look at the relative change in net worth. Figure 10 suggests that for the reference cohort (1911 generation) the yearly increase in net worth between ages 22 and 35 varied between 18% and 23%. These figures are considerably lower for the 1935 generation, namely between 4%

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<sup>34</sup> MDSS is the household specific average of SS over the sample period. In a balanced panel, MDSS is simply a cohort specific variable. Notice that the variable MDSS embodies all changes in the SS system which took place before 1987 (the beginning of the sample period). The coefficient corresponding to *DSS* is identified due to the interaction of the cohort and age effect and to changes in the SS system between 1987 and 1991.

<sup>35</sup> Note that this variable is an interaction term and therefore is not perfectly collinear with a full set of cohort dummies.

<sup>36</sup> As for *income*, this result is not driven by an “overparameterization” of the alternative model.

<sup>37</sup> Since we are interested in the displacement effect of SS, we keep *productivity* growth constant in the figures.

and 8.5%. The yearly increase between age 35 and 45 were from 19% to 23% for the 1911 generation, while they varied from 8% to 16% for the 1935 generation. Thus, in comparison with the cohorts that lived without SS for a part of their working life, the cohorts that had SS throughout their working life have less than half the accumulation rate of older cohorts.

## 5.2 Extensions

As is made clear in Appendix B, the model for wealth considered here can only be an approximation to a true model. In particular, we have ignored various interactions between fixed effects, productivity variables, and demographics. To investigate the extent to which our results would be affected by such simplification, we have considered several tests and modifications of our model. The first modification we investigate concerns the demographic variables, such as family size and number of children, considered in the estimation. In principle, the wealth equations should contain the complete time path of these variables since the beginning of one's (working) life. Since this information is unavailable, only current values have been included. As an approximation, one may assume that all these variables can be written as some function of age times a household specific constant. In that case the equation for wealth becomes a function of age interacted with several other variables like productivity, education and individual effects. Demographics then drop out, by construction (See equation (B. 13)). The empirical estimates of this reduced specification indicate some changes, although our main results remain the same. In particular, the SS variable continues to remain statistically significant in the case of total net worth. Financial net worth shows similar results with and without these demographics variables.<sup>38</sup>

As mentioned before, the chosen specification assumes that age, time, and cohort effects are additive. We have only allowed for interactions between the cohort and age effects in *DSS*. Clearly, there can be more complicated dynamics in wealth. We have therefore interacted the variables measuring cohort effects with time dummies, and with the polynomial in age. Our empirical estimates show that the interaction terms are not statistically significant.

As a further check for the existence of interactions and potentially other higher order terms, we work with savings which we derived by taking the first difference of (the hyperbolic sine of) *wealth*.<sup>39</sup> As we have seen

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<sup>38</sup> For brevity, these estimates are not reported but are available from the authors upon request.

<sup>39</sup> There are a few problems to consider when working with wealth in first differences. First, note that a large part of the first differences in wealth could be accounted for by capital gains on stocks and housing. Both stock and housing prices increased considerably in the period under consideration, even though, as we mention before, few households

in Section 2, and as was pointed out earlier by Deaton and Paxson (1994a,b) and Paxson (1996), savings rates (or relative changes in wealth) should display no cohort effects.

In the equations we estimate, we consider all the demographic variables and education in first differences, a fourth order polynomial in age, and three time dummies. In none of the specifications displayed in Table 4, are the variables proxying for the cohort effects statistically significant.<sup>40</sup> The null of no cohort effects is always accepted. These findings indicate that the additive structure we use may provide a good approximation for the behavior of wealth across different cohorts.

## 6. Conclusions

We have examined the income and wealth holdings of different cohorts. Many reasons have been proposed in the literature to explain why consumers born in different time periods have different paths of saving and wealth accumulation. People can differ in their tastes. For example, generations who lived through the Great Depression or World War II may be thriftier and more alert to risk than other generations. Additionally, generations could be different due to the diversity of economic conditions during their working lives. For example, the economy could have experienced high growth in wages, and changes in the SS system.

Our strategy consists of devising indicators that can summarize the economic conditions over time. A good proxy for the differences in the income profiles of households turns out to be GNP per capita around the time that the head of the household entered the labor market. Similarly, we have devised a proxy for the changes in the SS system at the beginning of or during the working life of the head of the household.

We find that income depends on productivity growth and that productivity growth and SS go a long way toward explaining the differences in wealth holdings across cohorts. One of the main features of the postwar economic development in the Netherlands has not only been the sharp increase in wages in the sixties, but also the rapid growth in the SS system. Both affect the wealth accumulation of people born in different periods of time. Given that we find that after inclusion of these variables, cohort effects are no longer

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hold stocks. Second, wealth has a very dispersed distribution which becomes even more dramatic when taking first differences. To be consistent with the previous results and to account for the high variation in wealth and saving, we continue to work with the hyperbolic sine transformation and take the difference of the transformed wealth levels rather than the levels themselves. This measure corresponds approximately to relative changes in wealth.

<sup>40</sup> We have performed these regressions for changes in financial net worth and results are the same. None of the variables indicating cohort effects are statistically significant.

significant, one may conjecture that differences across cohorts in wealth accumulation are not the result of differences in tastes, but rather due to differences in economic circumstances. The empirical estimates suggest that in comparison with the cohorts that lived without SS for a portion of their working life (they were born in 1911), the cohorts that always had SS (they were born in 1935 and after) have less than half the accumulation rates of older generations, in particular at young ages.

As mentioned in Section 2, there are other economic conditions that could be important for explaining the (cohort) differences in wealth accumulation, including precautionary motives, uncertain life time, (unanticipated) increases in house prices, bequest motives, changes in demographics and female labor supply. Undoubtedly, these factors play a role. The strategy in this paper has been, however, to simplify the model of wealth accumulation as far as possible and to still be able to explain important features of the data. We plan to investigate these other economic factors in future research.

## Appendix A: Social Security and wealth holdings.

We start the analysis by considering the closed-form solution for wealth in the PI-LCH. Initially, we abstract from the impact of productivity growth on wealth holdings. In what follows, we maintain the assumptions that preferences are quadratic and intertemporally separable and that the interest rate equals the rate of time preference. The inter-temporal budget constraint is written as:

$$c_t = (1+r)A_{t-1} + y_t - A_t \quad (\text{A.1})$$

where  $y_t$  is non-capital income at age  $t$ ,  $r$  is the interest rate,  $A_t$  is wealth at the end of period  $t$ ,  $c_t$  is consumption in period  $t$ . We adopt the convention that all income (both capital income and non-capital income) is received at the end of each period; the same holds for the timing of consumption.

It is rather easy to see that consumption in period  $t$  is equal to:

$$c_t = \left( \sum_{\tau=t}^L (1+r)^{t-\tau} \right)^{-1} \left( (1+r)A_{t-1} + \sum_{\tau=t}^L (1+r)^{t-\tau} E_t y_\tau \right) \quad (\text{A.2})$$

where  $L$  is the time horizon,  $E_t$  is the expectation operator conditional upon all information available at time  $t$ . From (A.1) and (A.2) one can derive that at the end of period  $t$  at wealth  $A_t$  satisfies the following equation:

$$\begin{aligned} A_t = & (1+r)^t A_0 + (1+r)^{t-1} y_1 + (1+r)^{t-2} E_1 y_2 + \dots + E_1 y_t \left( \frac{(1+r)^t - 1}{r} \right) Y_{p1} + (1+r)^{t-2} (y_2 - E_1 y_2) + \dots + (y_t - E_1 y_t) - \\ & \left( \left( \frac{(1+r)^{t-1} - 1}{r} \right) (c_2 - E_1 c_2) + \left( \frac{(1+r)^{t-2} - 1}{r} \right) (c_3 - E_2 c_3) + \dots + (c_t - E_{t-1} c_t) \right) \end{aligned} \quad (\text{A.3})$$

where  $Y_{p1}$  is permanent income evaluated in period 1 of the life cycle, defined as:

$$Y_{p1} \equiv \left( \sum_{\tau=1}^L (1+r)^{1-\tau} \right)^{-1} \left( (1+r)A_0 + \sum_{\tau=1}^L (1+r)^{1-\tau} E_1 y_\tau \right) = c_1 \quad (\text{A.4})$$

One can verify (A.3) by inserting the expressions for  $A_t$  and  $A_{t-1}$  into the intertemporal budget constraint (A.1) and by using the martingale property of consumption:  $c_t = E_t c_{t+1}$ .

The first part of (A.3) (until  $Y_{p,t}$ ) simply says that in the absence of new information, wealth is equal to (expected) accumulated saving. During the life cycle, new information becomes available so that the consumer replans his/her consumption and wealth paths. The remainder of the equation displays the effects of the revisions in income and the revisions in the consumption path respectively. We can elaborate equation (A.3) further:

$$\begin{aligned}
A_t = & (1+r)^t A_0 + (1+r)^{t-1} y_1 + (1+r)^{t-2} E_1 y_2 + \dots + E_1 y_t \left\{ \frac{(1+r)^t - 1}{r} \right\} Y_{p,t} + (1+r)^{t-2} (y_2 - E_1 y_2) + \dots + (y_t - E_1 y_t) - \\
& \left( \frac{(1+r)^{t-1} - 1}{r} \right) \left( \sum_{\tau=2}^L (1+r)^{2-\tau} \right)^{-1} \sum_{\tau=2}^L (1+r)^{2-\tau} (E_2 - E_1) y_\tau - \left( \frac{(1+r)^{t-2} - 1}{r} \right) \left( \sum_{\tau=3}^L (1+r)^{3-\tau} \right)^{-1} \sum_{\tau=3}^L (1+r)^{3-\tau} (E_3 - E_2) y_\tau \\
& \dots - \left( \sum_{\tau=t}^L (1+r)^{t-\tau} \right)^{-1} \sum_{\tau=t}^L (1+r)^{t-\tau} (E_t - E_{t-1}) y_\tau
\end{aligned} \tag{A.5}$$

This expression is useful to highlight the effects on wealth of both the introduction of SS and later revisions in the level of SS. We assume that individuals hold static expectations concerning the future level of  $SS^{41}$ . That is, at each age  $k$  they plan their consumption as if the level of SS will remain constant during the course of their lifetime. Furthermore, we initially assume that individuals ignore any possible feedback effect of SS on their current income (e.g. through a change in taxes). If a revision takes place the individuals update their expectations to the new SS-level. One can use (AS) to trace the effects of the introduction of SS and subsequent revisions on the accumulation of wealth.

First consider the effect on wealth of someone who has not retired yet. Assume that individuals retire at age  $L_p$ , i.e. they start receiving SS in period  $L_p + 1$ , so we consider the case where  $t \leq L_p$ . Using (AS) we first look at the effects of SS on  $Y_{p,t}$ . Let  $SS_t$  be the level of SS anticipated by the individual when his age is  $t$ . Using (A.4) one sees immediately that relative to a situation without SS,  $Y_{p,t}$  is only **affected** by the term:

$$\left( \sum_{\tau=1}^L (1+r)^{1-\tau} \right)^{-1} \left( \sum_{\tau=L_p+1}^L (1+r)^{1-\tau} SS_t \right) = (1+r)^{-L_p} \cdot \frac{1 - (1+r)^{L_p-L}}{1 - (1+r)^{-L}} \cdot SS_t \tag{A.6}$$

Next we notice that in (AS) all income terms dated earlier than  $t$  are by assumption unaffected by changes in SS. The only other terms **affected** by changes in SS are the terms involving the update in expectations from one period to the next. For example, for  $k \leq t$  we have the following effect of a change in SS at age  $k$ :

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<sup>41</sup> Or equivalently, that shocks in SS are taken to be permanent.

$$\sum_{\tau=k}^L (1+r)^{k-\tau} (E_k - E_{k-1}) y_{\tau} = \sum_{\tau=L_1+1}^L (1+r)^{k-\tau} \cdot SS_k^* = (1+r)^{k-L_1} \left[ \frac{1 - (1+r)^{L_1-L}}{r} \right] \cdot SS_k^* \quad (A.7)$$

where  $SS_k$  is the level of SS anticipated at age  $k$ , and  $SS_k^* = SS_k - SS_{k-1}$  for  $k \geq 2$ .

Defining  $SS_t^* = SS_t$  and inserting (A.6) and (A.7) into (AS) we obtain the following “displacement” effect of SS (in comparison to a world without SS) on the wealth holdings of individuals of age  $t$  who are not retired yet:

$$DSS_t = - \sum_{k=1}^t \left( \frac{(1+r)^{t-k+1} - 1}{(1+r)^{L-k+1} - 1} \right) \left( \frac{(1+r)^{L-L_1} - 1}{r} \right) SS_k^*, \text{ for } t \leq L_1 \quad (A.8)$$

For retired individuals ( $t > L_1$ ) the analysis is quite a bit simpler. To start we note that the effect of SS on their wealth holdings at retirement (i.e. at the end of period  $L_1$ ) is obtained from (A.8) by inserting  $t = L_1$ . This yields:

$$DSS_{L_1} = - \sum_{k=1}^{L_1} \left( \frac{(1+r)^{L_1-k+1} - 1}{(1+r)^{L-k+1} - 1} \right) \left( \frac{(1+r)^{L-L_1} - 1}{r} \right) SS_k^* \quad (A.9)$$

Next we observe that under our assumptions any change in SS after retirement is considered to be permanent by the individual, and hence translates into a corresponding change in consumption. As a result, wealth holdings after retirement are not affected by changes in SS that take place after  $L_1$ . Hence, the effect of SS on wealth holdings after retirement is obtained by considering the time path along which  $DSS_{L_1}$  is consumed towards the end of the life cycle. In each period an amount:

$$c \equiv \left[ \sum_{\tau=L_1+1}^L (1+r)^{L_1+1-\tau} \right]^{-1} \cdot DSS_{L_1} (1+r) = \frac{r}{1 - (1+r)^{L_1-L}} \cdot DSS_{L_1} \quad (A.10)$$

will be consumed. Thus at age  $t > L_1$  the effect of SS on wealth holdings is equal to:

$$DSS_t = DSS_{L_1} \cdot \left[ \frac{1-(1+r)^{t-L}}{1-(1+r)^{L_1-L}} \right] = - \left( \frac{(1+r)^{L-L_1}-1}{r} \right) \cdot \left[ \frac{1-(1+r)^{t-L}}{1-(1+r)^{L_1-L}} \right] \cdot \sum_{k=1}^{L_1} \left( \frac{(1+r)^{L_1-k+1}-1}{(1+r)^{L-k+1}-1} \right) SS_k^* \quad (\text{A.11})$$

Let us now relax the assumption that the introduction of SS does not affect the income of the working population. Instead we assume that corresponding to a given level  $SS$  a payroll tax is levied equal to  $\alpha SS$ . For simplicity we take  $\alpha$  to be a constant. This would, for instance, correspond to a stationary population and a strict pay-as-you-go system. In that case  $\alpha$  is equal to the ratio of the number of SS recipients to the number of workers. We will see below that a generalization to a non-constant  $\alpha$  is straightforward.

Once again we take (AS) as a starting point. First consider the effect of the payroll tax associated with  $SS_t$  on  $Y_{p,t}$ . Using (A.4) we obtain a negative effect of a permanent payroll tax of  $\alpha SS_t$  on  $Y_{p,t}$  equal to:

$$\alpha SS_t \left[ \sum_{\tau=1}^L (1+r)^{1-\tau} \right]^{-1} \left( \sum_{\tau=1}^{L_1} (1+r)^{1-\tau} \right) = \alpha SS_t \frac{(1+r)^L - (1+r)^{L-L_1}}{(1+r)^L - 1} \quad (\text{A. 12})$$

In addition, the income terms on the first line of (AS) up to  $Y_{p,t}$  are affected. The total effect of a payroll tax equal to  $\alpha SS_t$  on these income terms is equal to

$$((1+r)^{t-1} + (1+r)^{t-2} + \dots + 1) \alpha SS_t = \frac{(1+r)^t - 1}{r} \alpha SS_t \quad (\text{A.13})$$

Combining (AS), (A. 12), and (A. 13) we find the total negative effect of a payroll tax equal to  $\alpha SS_t$  on wealth accumulation at age  $t$  to be equal to:

$$\alpha SS_t \frac{(1+r)^t - 1}{r} \left( \frac{(1+r)^{L-L_1} - 1}{(1+r)^L - 1} \right) \quad (\text{A. 14})$$

Now consider the effect of a change in SS at age  $k$ . This effect also consists of two parts. The first part is:



$$\left[ (1+r)^{t-k} + (1+r)^{t-k-1} + \dots + 1 \right] \alpha SS_k^* = \frac{(1+r)^{t-k+1} - 1}{r} \alpha SS_k^* \quad (\text{A. 15})$$

The second part is:

$$\begin{aligned} & -\alpha SS_k^* \left( \frac{(1+r)^{t-k+1} - 1}{r} \right) \left( \sum_{\tau=k}^L (1+r)^{k-\tau} \right)^{-1} \left( \sum_{\tau=k}^{L_1} (1+r)^{k-\tau} \right) = \\ & -\alpha SS_k^* \left[ \frac{(1+r)^{t-k+1} - 1}{(1+r)^{L-k+1} - 1} \right] \left[ \frac{(1+r)^{L-k+1} - (1+r)^{L-L_1}}{r} \right] \end{aligned} \quad (\text{A. 16})$$

Adding both parts yields:

$$\alpha SS_k^* \left[ \frac{(1+r)^{t-k+1} - 1}{r} \right] \left[ \frac{(1+r)^{L-L_1} - 1}{(1+r)^{L-k+1} - 1} \right] \quad (\text{A. 17})$$

Comparing (A. 17) to (A. 14) shows that (A. 17) applies for all  $k$ , also  $k=L$ . Finally, by aggregating over all  $k \leq t$ , we obtain for the total effect of the payroll tax on wealth at age  $t$ :

$$-\alpha \sum_{k=1}^t SS_k^* \left[ \frac{(1+r)^{t-k+1} - 1}{r} \right] \left[ \frac{(1+r)^{L-L_1} - 1}{(1+r)^{L-k+1} - 1} \right] \quad (\text{A. 18})$$

Comparing this to (A.8), we observe that apart from a factor  $a$ , (A. 18) is exactly equal to (A.8). The intuition for this is straightforward. Under the assumptions made, consumption **is** constant across the life cycle. Given the age of retirement, savings during the working life are exclusively a function of the difference in incomes between retirement and the working life. An increase in income during retirement therefore has exactly the same effect as a reduction in income during the working life.

A generalization to the case where the payroll tax varies across age is straightforward. The factor  $a$  is replaced by  $\alpha_k$  and in (A. 18)  $\alpha_k$  is moved under the summation sign.

Finally, the case where  $t > L_1$  is an obvious adaptation of (A. 11): one simply pre-multiplies (A. 11) by  $a$ . The total effect of SS after retirement and a payroll tax before retirement is  $(1+\alpha)$  times (A.8) and (A. 11) respectively.

In our empirical work, we compute (A.8) and (A. 11) for all possible ages  $t$  and for all generations which

we observe in our sample. These expressions for the SS-effect are next adjusted in two ways. The first adjustment is related to the functional form for wealth chosen in our empirical work (the hyperbolic sine; see Section 4), and the second to the fact that there is productivity growth in the economy. Note that the SS variable is derived under the assumption of no productivity growth. In order to correct for productivity growth and for the fact that the hyperbolic sine of wealth is our dependent variable, we have replaced  $DSS_t$  in equations (A.8) and (A. 11) by the following expression:

$$\ln \left( 1 + \sum_{k=1}^t a_k \left( \frac{SS_k^g}{GNPC_k^g} - \frac{SS_k^r}{GNPC_k^r} \right) \right) \quad (\text{A.19})$$

where the superscript  $g$  indicates generation  $g$  and the superscript  $r$  the ‘reference generation’. The exact expression of the terms  $a_k$  within the sum sign which depend on  $L$ ,  $L_t$  and the interest rate  $r$ , directly follow from equations (A.8) and (A. 11). Equation (A. 19) can be justified by a crude approximation, which follow from ‘log-linearizing’ the wealth equation. In doing the log-linearization of the wealth equation, however, we have to be rather careful in choosing the reference group. The 19 11 generation (the oldest generation in our sample) seems a reasonable choice of reference group. The log-linearized version of the model is not used to predict the wealth profile of the generation without any SS. Since such households are not observed in our sample, the quality of the log-linear approximation can become rather poor.

## Appendix B: Demographic translating and scaling, human capital and productivity growth.

In this appendix we investigate the effects of demographics and differences in productivity and human capital on the lifetime wealth profiles of cohorts. The main purpose is to characterize the various interactions between these effects in the determination of household wealth. For simplicity we assume complete certainty.

### *Demographic translating and scaling*

Consider the following maximization problem:

$$\begin{aligned} \mathbf{max} \quad & -\frac{1}{2} \sum_{t=1}^L \rho^{t-1} \left( \frac{c_t - g_t}{f_t} \right)^2 \\ \text{s.t.} \quad & c_t = (1+r)A_{t-1} + y_t - A_t \\ & A, \text{ given, } A_L = 0 \end{aligned} \tag{B.1}$$

where  $g_t$ <sup>42</sup> and  $f_t$  are functions of the composition of the household. Assume as in Section 2, that the time preference rate and interest rate are equal, i.e.  $\rho = (1+r)^{-1}$ . Ignore the scaling parameter  $f_t$  for the moment.

Define  $c_t^* \equiv c_t - g_t$  and  $y_t^* \equiv y_t - g_t$  and rewrite the maximization problem as

$$\begin{aligned} \max \quad & \sum_{t=1}^L \rho^{t-1} - \frac{1}{2} (c_t^*)^2 \\ \text{s.t.} \quad & c_t^* = (1+r)A_{t-1} + y_t^* - A_t \\ & A, \text{ given, } A_L = 0 \end{aligned} \tag{B.2}$$

This is now in exactly the same form as given in Section 2 with  $c_t^*$  replacing  $c_t$ . The solution for wealth at age  $t$  is therefore

$$A_t = (1+r)^{t-1} \left( (1+r)A_0 + \sum_{\tau=1}^t (1+r)^{1-\tau} (y_\tau^* - g_\tau^*) \right) \tag{B.3}$$

with  $Y_p^*$  defined as

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<sup>42</sup> Note that  $g$  includes the “Bliss” level of consumption.

$$Y_p^* = \left( \sum_{\tau=1}^L (1+r)^{1-\tau} \right)^{-1} \left( (1+r)A_0 + \sum_{\tau=1}^L (1+r)^{1-\tau} [y_\tau - g_\tau] \right) \quad (\text{B.4})$$

The introduction of the scale parameter  $f_t$  complicates the expression for wealth somewhat more. With some straightforward but slightly tedious algebra we find that the expression for  $A$ , obtained by taking into account both translating and scaling is:

$$A_t = (1+r)^{t-1} \left( (1+r)A_0 + \sum_{\tau=1}^t (1+r)^{1-\tau} (y_\tau - g_\tau - f_\tau^2 \bar{Y}_p) \right) \quad (\text{B.5})$$

with

$$\bar{Y}_p = \left( \sum_{\tau=1}^L (1+r)^{1-\tau} f_\tau^2 \right)^{-1} \left( (1+r)A_0 + \sum_{\tau=1}^L (1+r)^{1-\tau} [y_\tau - g_\tau] \right) \quad (\text{B.6})$$

### *Human capital and productivity growth*

Consistent with the specification for household income given in Section 4 (cf. (5)) we specify the following equation for income at age  $\tau$ :

$$y_\tau = k_y \cdot h(\tau) \cdot \phi(x_\tau) \cdot \psi(c) \quad (\text{B.7})$$

where we have ignored time dummies for notational simplicity. For the rest, income is decomposed in a household specific effect  $k_y$ , a function of age,  $h(\tau)$ , a function of possibly varying explanatory variables (like education),  $\phi(x_\tau)$ , and a cohort effect which may include productivity differentials across cohorts,  $\psi(c)$ . As a result of this specification, we can write:

$$\sum_{\tau=1}^t (1+r)^{1-\tau} y_\tau = k_y \cdot \psi(c) \cdot \sum_{\tau=1}^t (1+r)^{1-\tau} h(\tau) \cdot \phi(x_\tau) \quad (\text{B.8})$$

Inserting this in (B.5) we obtain:

$$A_t = (1+r)^{t-1} \left( (1+r)A_0 + k_y \cdot \psi(c) \cdot \sum_{\tau=1}^t (1+r)^{1-\tau} h(\tau) \cdot \varphi(x_\tau) - \sum_{\tau=1}^t (1+r)^{1-\tau} (g_\tau + f_\tau^2 \bar{Y}_p) \right) \quad (\text{B.9})$$

Clearly, (B.9) comprises various unobservable terms pertaining to the past. A simple way to get around this difficulty is to assume that we may approximate various time varying expressions as a product of an age function and a household specific effect:

$$f_\tau = f(\tau) \cdot k_f; \quad g_\tau = g(\tau) \cdot k_g; \quad \varphi(x_\tau) = \lambda_1(x) \cdot \lambda_2(\tau) \quad (\text{B.10})$$

where  $k_f$  and  $k_g$  are household specific constants and the functions  $f, g, \lambda_1, \lambda_2$  are left unspecified. This allows us to approximate (B.9) as follows:

$$A_t = (1+r)^{t-1} \left( (1+r)A_0 + k_y \cdot \psi(c) \cdot \lambda_1(x) \cdot \sum_{\tau=1}^t (1+r)^{1-\tau} h(\tau) \cdot \lambda_2(\tau) - \sum_{\tau=1}^t (1+r)^{1-\tau} [k_g \cdot g(\tau) + k_f^2 \cdot f(\tau)^2 \bar{Y}_p] \right) \quad (\text{B.11})$$

For an easy interpretation of this expression, define the following quantities:

$$\begin{aligned} (1+r)^t A_0 &\equiv \delta_1(t) \cdot k_A; & \sum_{\tau=1}^t (1+r)^{t-\tau} h(\tau) \cdot \lambda_2(\tau) &= \delta_2(t); \\ \sum_{\tau=1}^t (1+r)^{t-\tau} [k_g \cdot g(\tau) + f(\tau)^2 \bar{Y}_p \cdot k_f^2] &= k_g \cdot \delta_3(t) + \delta_4(t) \cdot \bar{Y}_p \cdot k_f^2 \end{aligned} \quad (\text{B.12})$$

where  $k_A$  is a household specific constant. Thus we can rewrite (B.11) as follows:

$$A_t = \delta_1(t) \cdot k_A + k_y \cdot \psi(c) \cdot \lambda_1(x) \cdot \delta_2(t) - [k_g \cdot \delta_3(t) + \delta_4(t) \cdot \bar{Y}_p \cdot k_f^2] \quad (\text{B.13})$$

From (B.13) one can see that the expression for household wealth depends on complicated interactions between household **specific** constants, age functions, and productivity variables. The essentially log-linear form we have adopted for the description of the wealth holdings of households therefore cannot be more than a crude approximation of the true linear form. To gauge the extent to which our approximation is adequate it is important to test for the statistical significance of the various possible interactions, as has been done in Section 5.2.

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Table 1: Distribution of Financial and Total Net Worth

Distribution	Financial Net Worth	Total Net Worth	Financial Net Worth	Total Net Worth
	1987	1987	1991	1991
10 <sup>th</sup> percentile	-1571	-1200	-609	9
25 <sup>th</sup> percentile	2000	2764	2790	4571
Median	9220	16923	12183	25111
75 <sup>th</sup> percentile	22300	72203	30226	93712
90 <sup>th</sup> percentile	44000	154193	65567	198094
99 <sup>th</sup> percentile	223382	482500	288776	571674
Mean	20294	55718	28835	73082
(s.d.)	(53058)	(105240)	(68395)	(127803)

This table reports the distribution of financial and total net worth in 1987 and 1991 across **percen** tiles. All values are expressed in 1987 Dutch Guilders.

Table 2: Household Income

	Specification 1		Specification 2		Specification 3	
Variables	estimate	st. error	estimate	st. error	estimate	st. error
ln(RGNPC)			0.358	0.078		
age/10	10.972	1.749	10.207	1.429	8.876	1.400
(age/10) <sup>2</sup>	-4.671	0.802	-4.370	0.652	-3.661	0.633
(age/10) <sup>3</sup>	0.997	0.176	0.930	0.143	0.750	0.138
(age/10) <sup>4</sup>	-0.104	0.019	-0.097	0.015	-0.076	0.014
(age/10) <sup>5</sup>	0.004	0.001	0.004	0.001	0.003	0.001
time dummy (year=1985)	-0.007		-0.001	0.008	0.009	0.008
time dummy (year= 1986)	0.004	0.004	0.018	0.009	0.038	0.008
time dummy (year=1987)	-0.010	0.004	0.013	0.010	0.043	0.008
time dummy (year=1988)	0.001	0.004	0.033	0.012	0.073	0.008
time dummy (year=1989)	0.005	0.003	0.046	0.014	0.096	0.008
constant	-1.714	1.472	-3.767	1.566	0.905	1.190
demographics	yes		yes		yes	
cohort dummies	yes		no		no	
Overall R <sup>2</sup>	0.4499		0.4435		0.4427	
Wald test of the hypothesis that coefficients of the time dummies are orthogonal to a time trend						
$\chi^2$			7.57		90.57	
degrees of freedom			1		1	
p-value			0.0059		0.0000	
Wald test against a model with a full set of cohort dummies						
$\chi^2$			73.42		94.48	
degrees of freedom			52		53	
p-value			0.0268		0.0004	

Note: This table reports the estimation results for household income in logs. The number of observations is 18,485. Even though not **reported**, the regressions contain demographic variables for gender, education, number of children, and number of adults in the household. In the bottom panel, the table reports two Wald tests. Refer to the text for a discussion of these tests.

Table 3 : Household Wealth

	Total Net Worth		Financial Net Worth	
	Cohort effects: Prod. Growth & s. security		Cohort effects: Prod. Growth & s. security	
Variables	estimate	standard error	estimate	standard error
ln(RGNPC)	1.551	1.308	0.935	1.356
DSS				
MDSS				
DSS	1.716	2.725	-2.510	2.908
MDSS	-4.278	1.087	-0.813	1.171
age/10	-4.982	25.554	36.039	27.346
(age/10) <sup>2</sup>	2.704	10.931	-13.532	11.702
(age/10) <sup>3</sup>	-0.443	2.310	2.615	2.473
(age/10) <sup>4</sup>	0.031	0.237	-0.245	0.254
(age/10) <sup>5</sup>	-0.001	0.009	0.009	0.010
time dummy (year=1988)	-0.334	0.414	-0.337	0.457
time dummy (year=1989)	-0.341	0.431	-0.423	0.474
time dummy (year=1990)	0.011	0.508	0.285	0.557
time dummy (year=1991)	0.234	0.619	0.604	0.678
constant	3.105	23.536	-34.97	25.175
demographics	yes		yes	
Overall R <sup>2</sup>	0.091		0.067	
Wald test of the hypothesis that coefficients of the time dummies are orthogonal to a time trend				
$\chi^2(1)$ (p-value)	0.031 (0.860)		0.160 (0.693)	
Wald test of the hypothesis on the joint significance of the SS variables				
$\chi^2(2)$ (p-value)	45.970 (0.000)		9.090 (0.011)	
Wald test against a model with a full set of cohort dummies				
$\chi^2(52)$ (p-value)	45.660 (0.720)		38.900 (0.911)	

Note: This table reports the estimation results for household net worth and financial wealth transformed using the hyperbolic sine. The number of observations is 17,154. Even though not reported, the regressions contain demographic variables for gender, education, number of children, and number of adults in the household. In the bottom panel, the table reports three Wald tests. Refer to the text for a discussion of these tests.

Table 4: Household Saving

	Specification 1		Specification 2		Specification 3		Specification 4	
	estimate	st. error	estimate	st. error	estimate	st. error	estimate	st. error
RGNPC			-0.783	0.799	-0.993	0.798		
MDSS			-1.453	1.413				
DSS			4.536	2.856				
$\Delta$ DSS					-0.680	6.381		
year = 1989	-0.044		-0.104	0.121	-0.062	0.118	-0.084	0.11
year = 1990	0.094	0.065	-0.046	0.139	0.065	0.124	0.015	0.115
year = 1991	-0.048	0.043	-0.270	0.170	-0.094	0.131	-0.165	0.115
age/10	14.148	14.442	-1.849	6.381	3.039	5.667	-0.591	4.758
$(age/10)^2$	-4.129	4.682	-0.239	1.763	-0.720	1.739	0.304	1.505
$(age/10)^3$	0.468	0.642	0.053	0.224	0.047	0.225	-0.059	0.203
$(age/10)^4$	-0.018	0.032	0.000	0.011	0.000	0.011	0.004	0.01
constant.	-13.83	15.967	12.867	8.091	6.828	7.636	0.791	5.411
$\Delta$ demographics	yes		yes		yes		yes	
cohort dummies	yes		no		no		no	
R <sup>2</sup>	0.0060		0.0046		0.0044		0.0042	

This table reports the estimation results for saving, which are derived by first differencing the hyperbolic sine of wealth. Variables **startin** g with A indicate first differences. The number of observations is 12,204.

Figure 1a: The effect of the introduction of social security on consumption

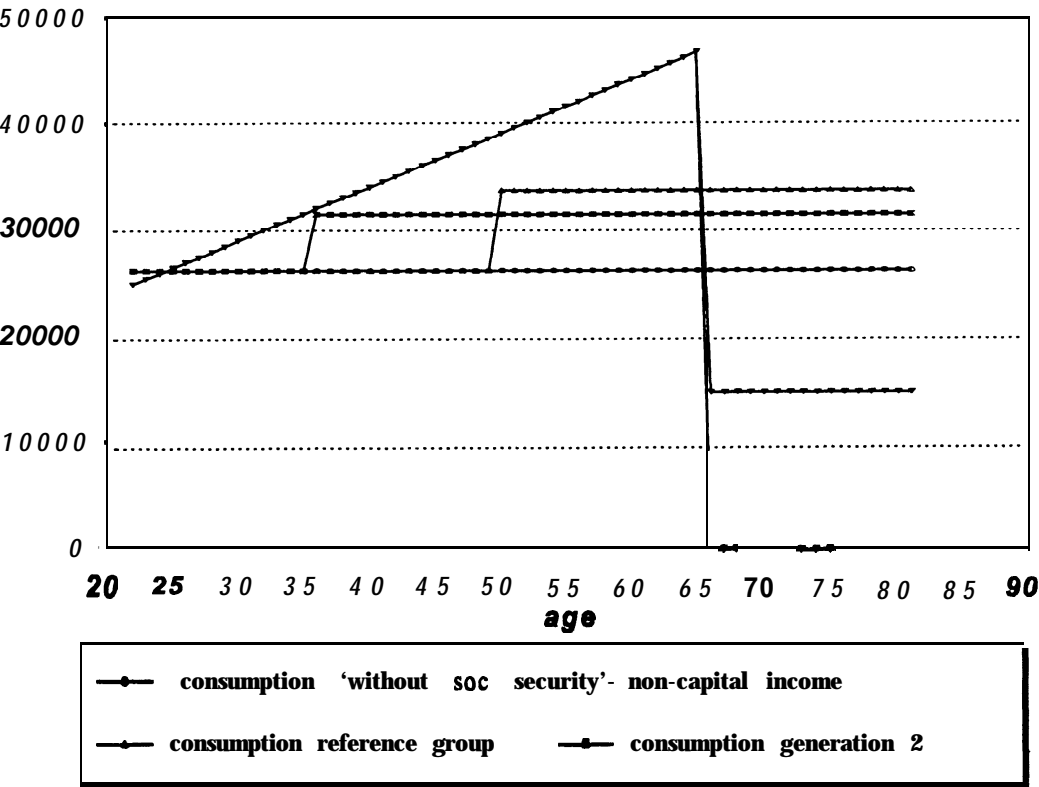


Figure 1b: The effect of the introduction of social security on wealth

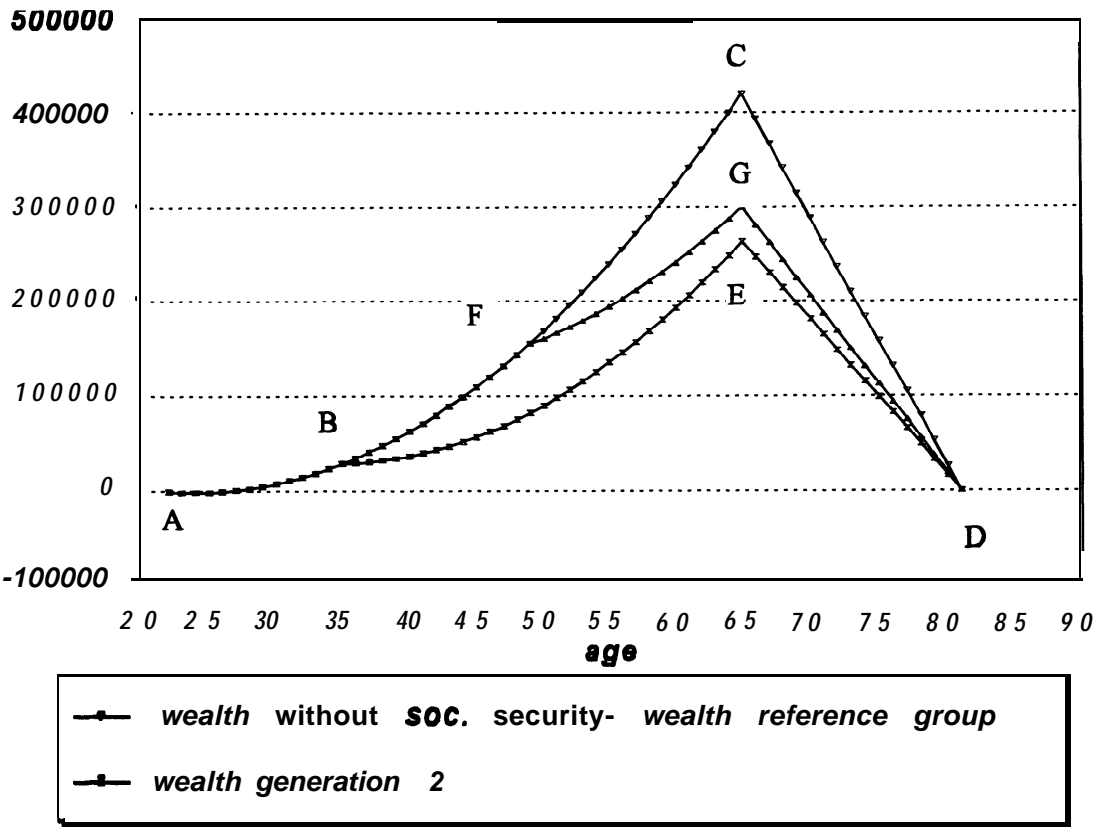


Figure 2a

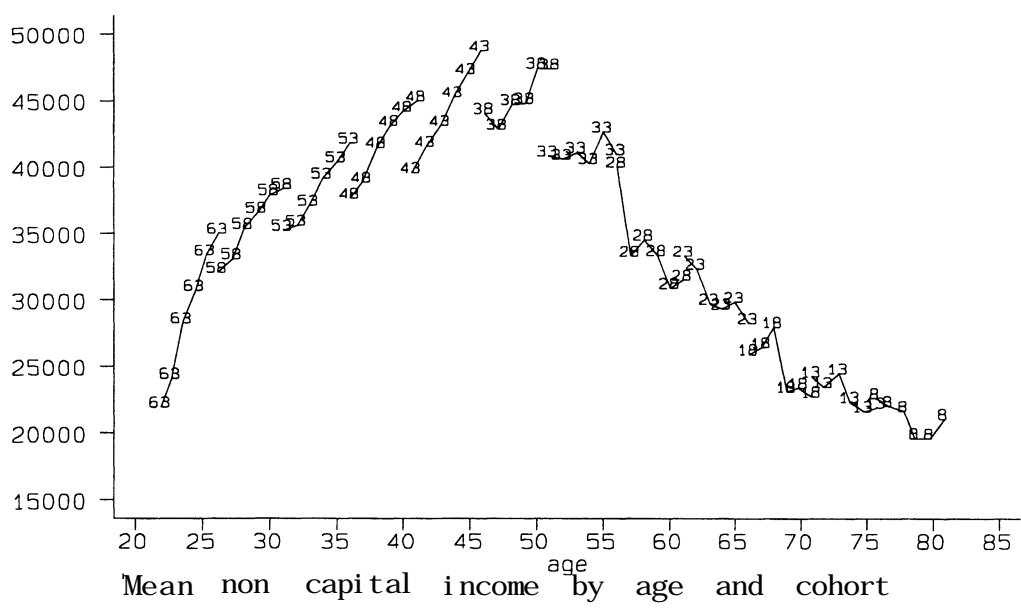


Figure 2b

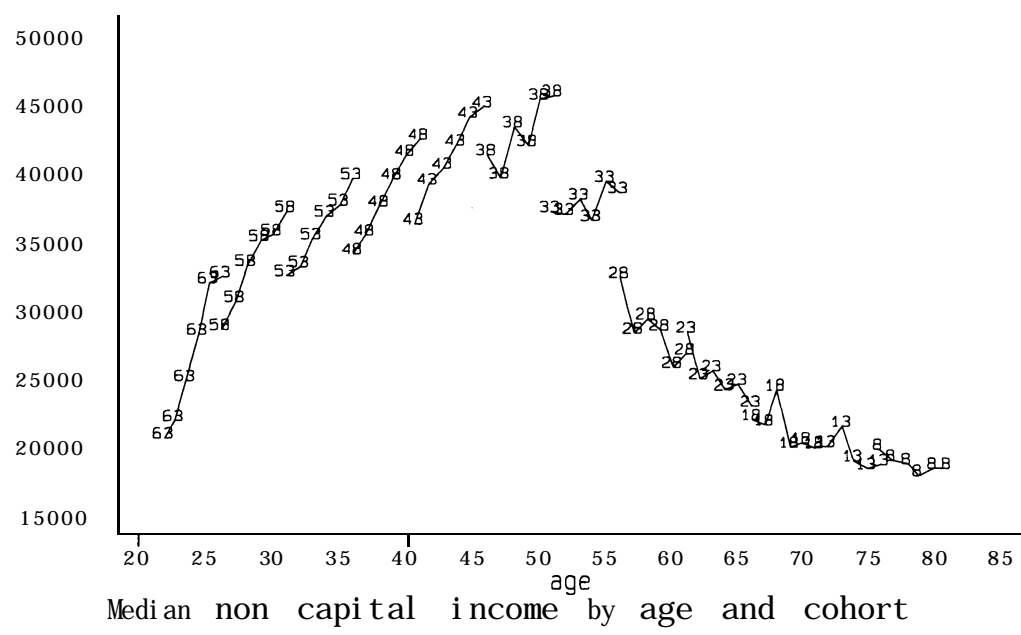


Figure 3

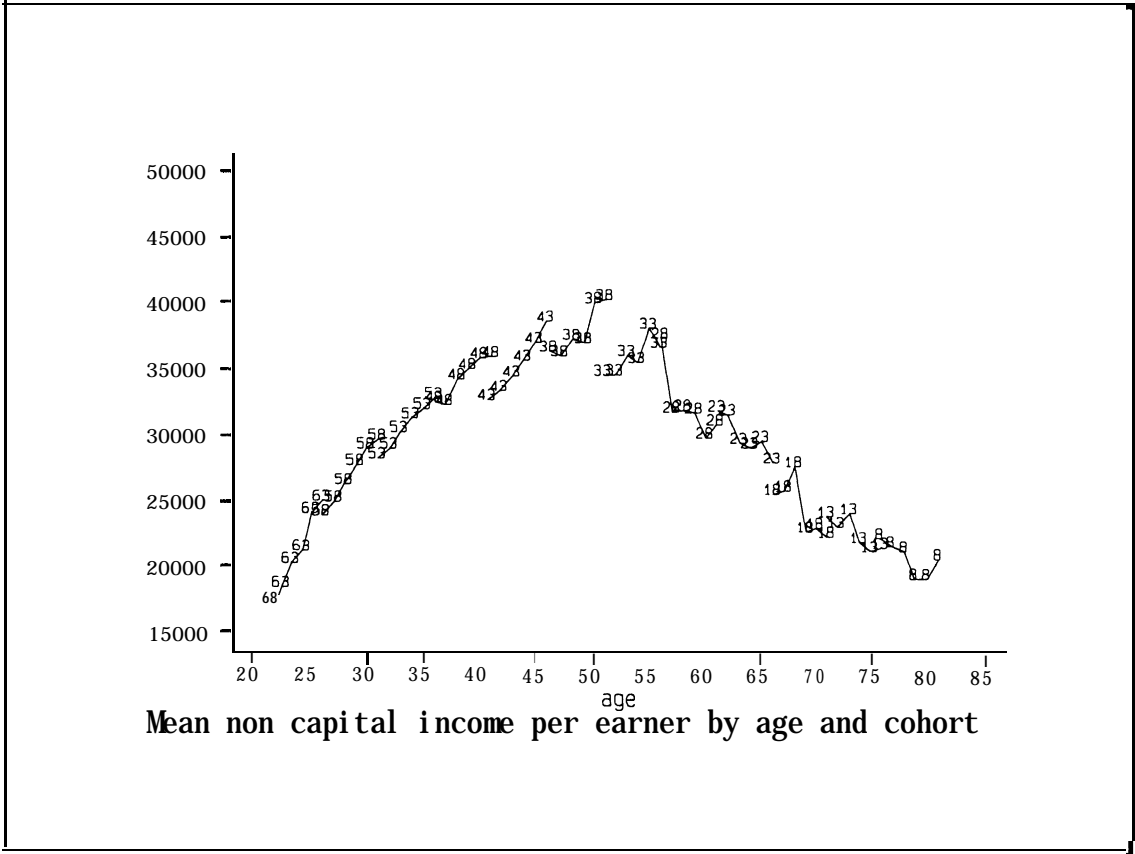




Figure 4a

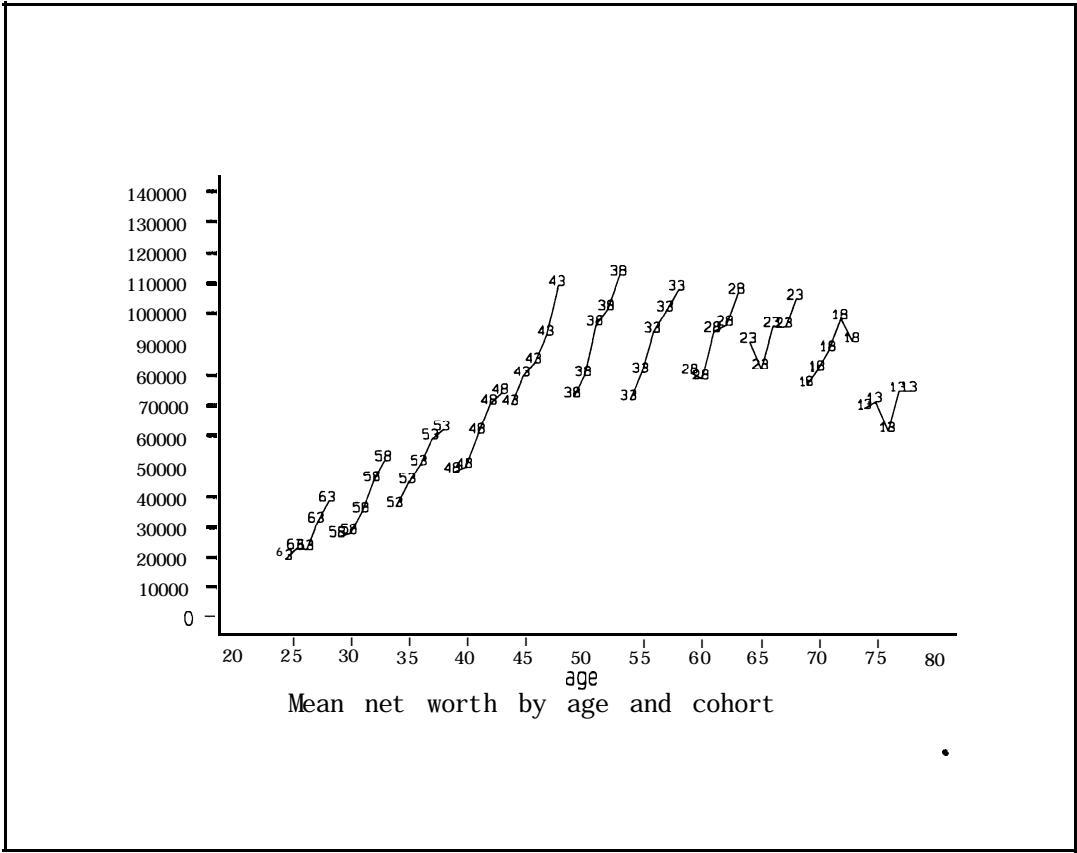


Figure 4b

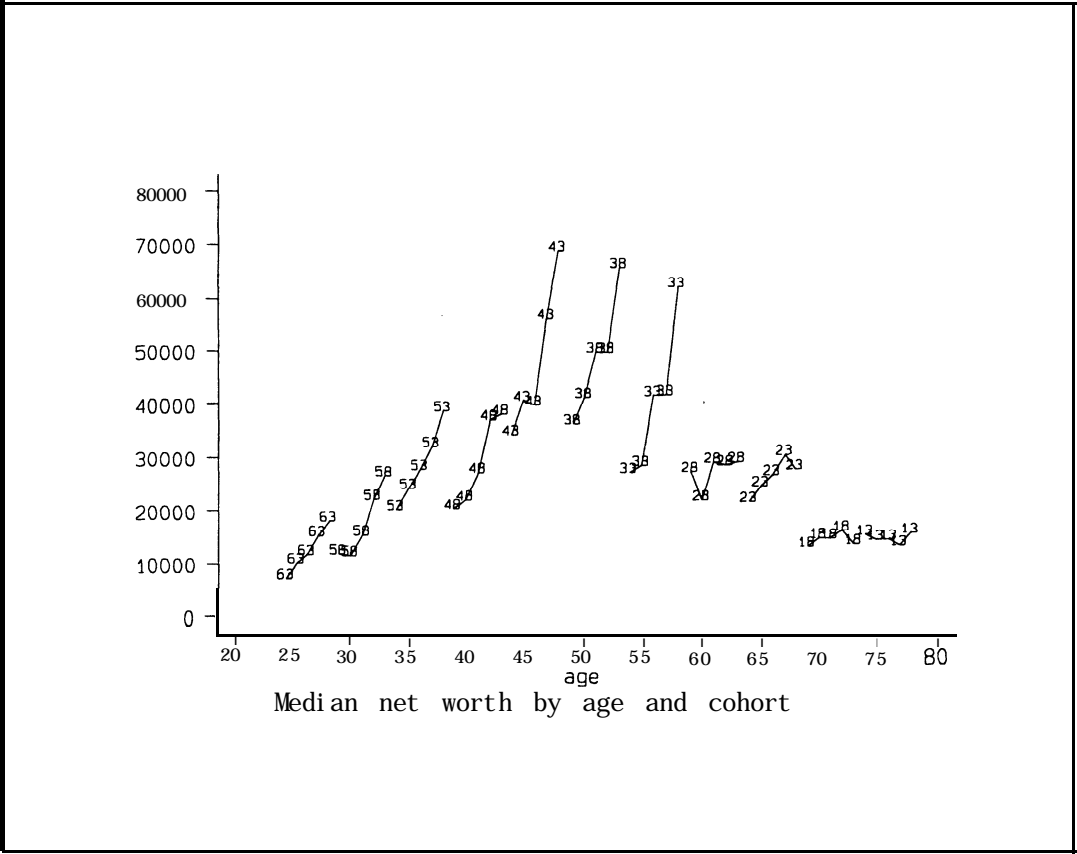


Figure 5

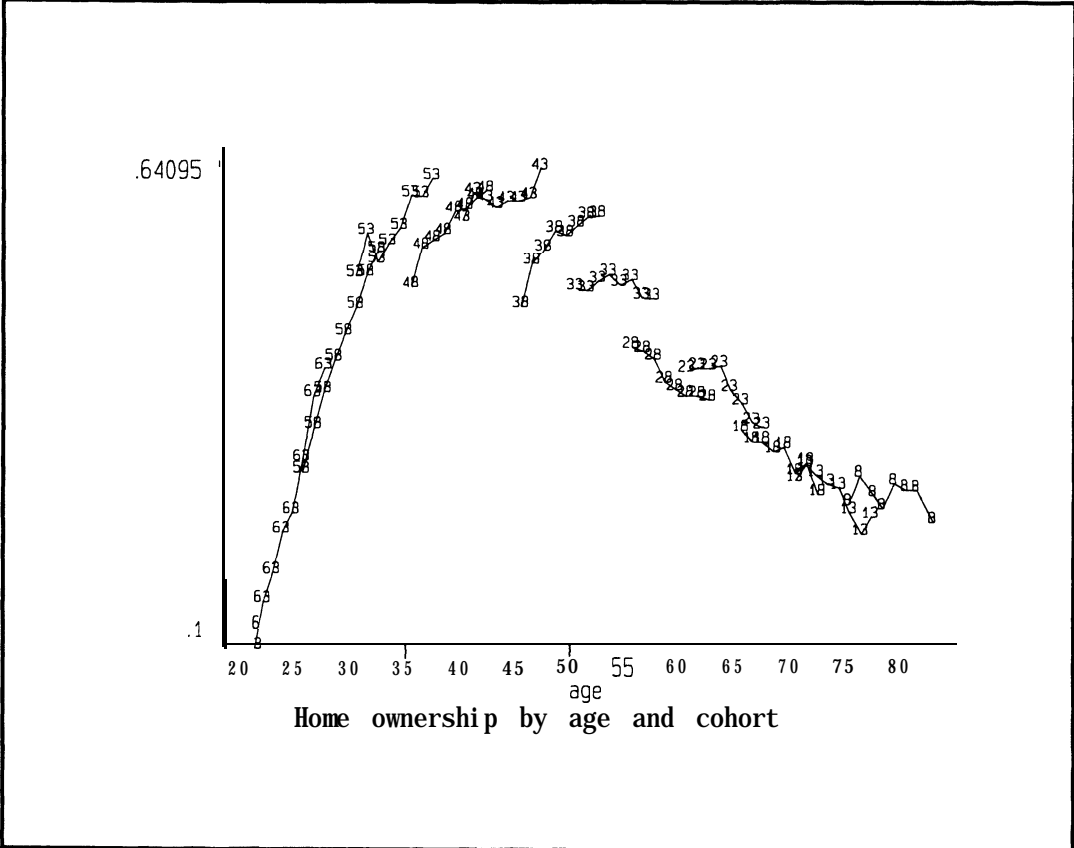


Figure 6a

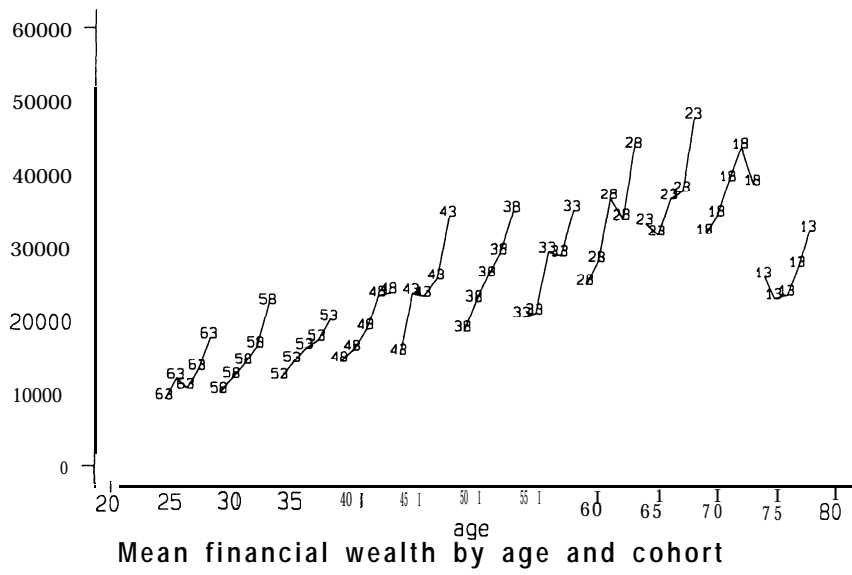


Figure 6b

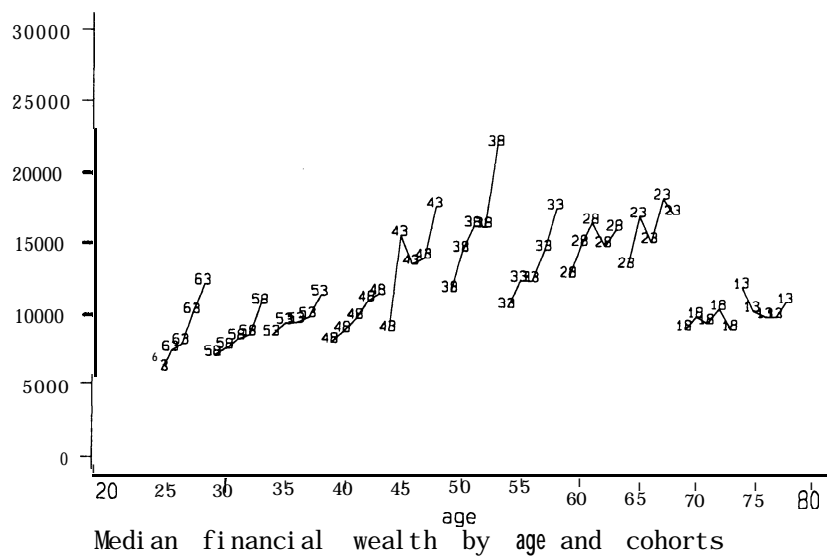


Figure 7

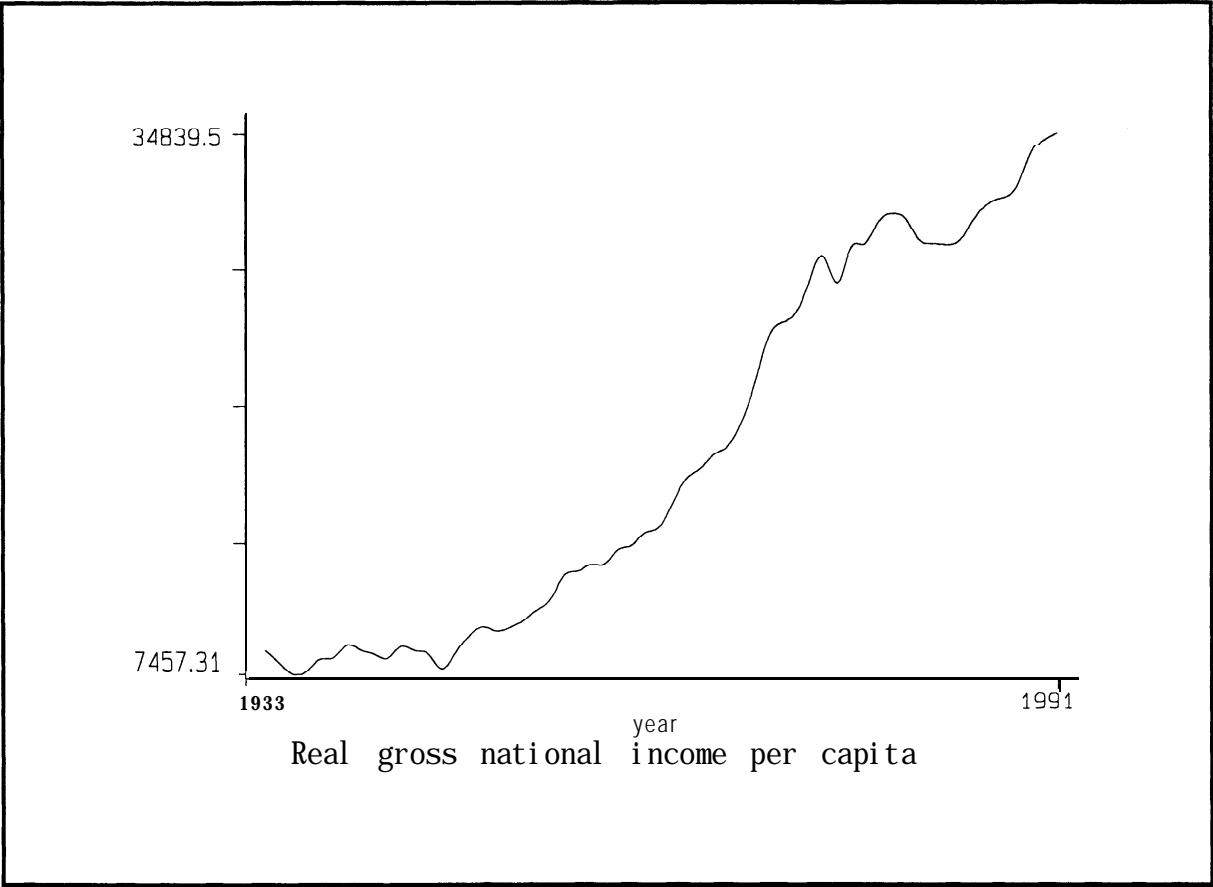
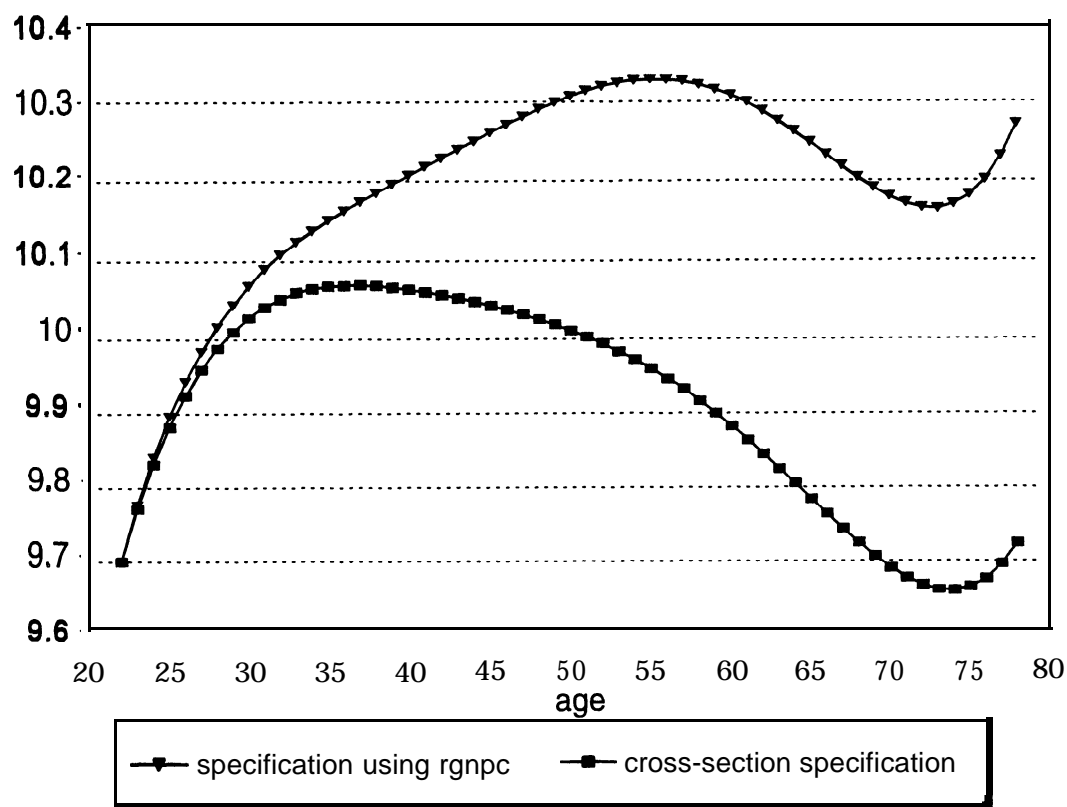


Figure 8: The age income profiles according to 2 different models



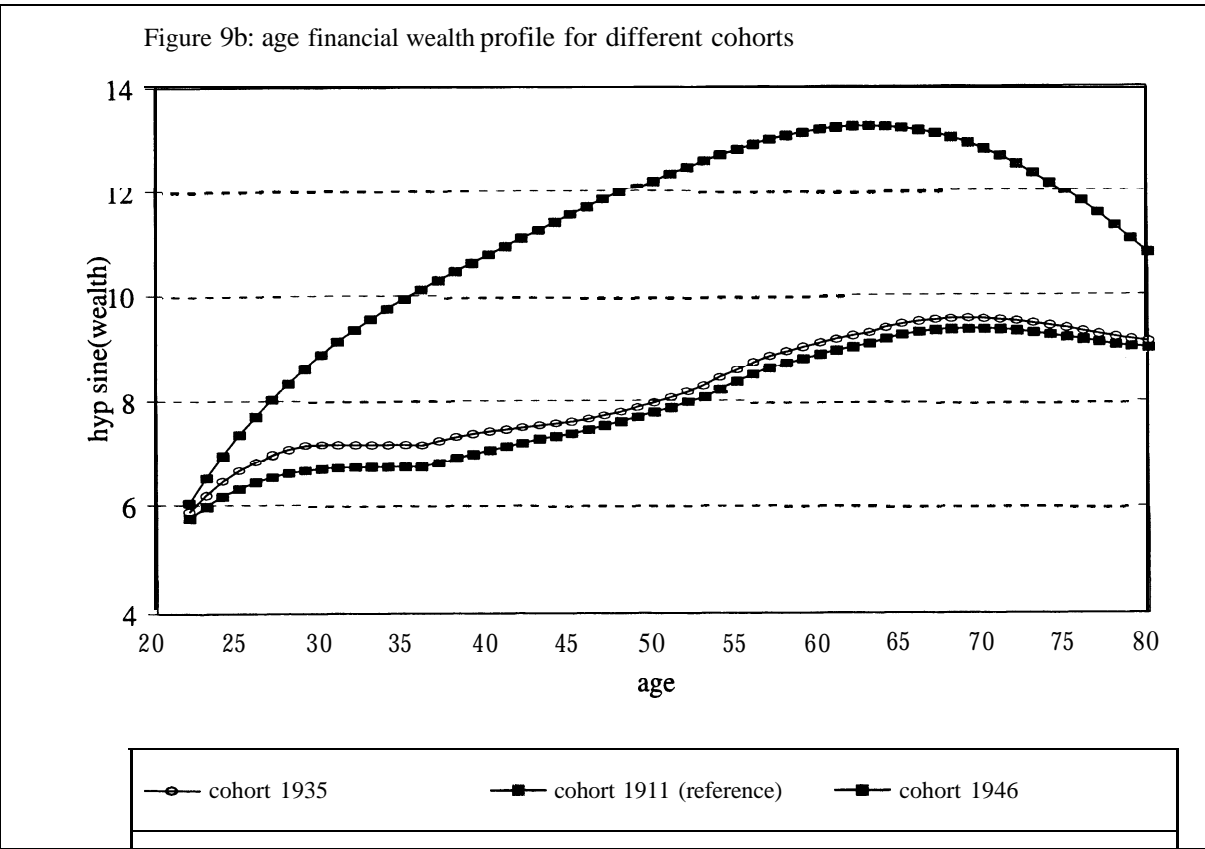
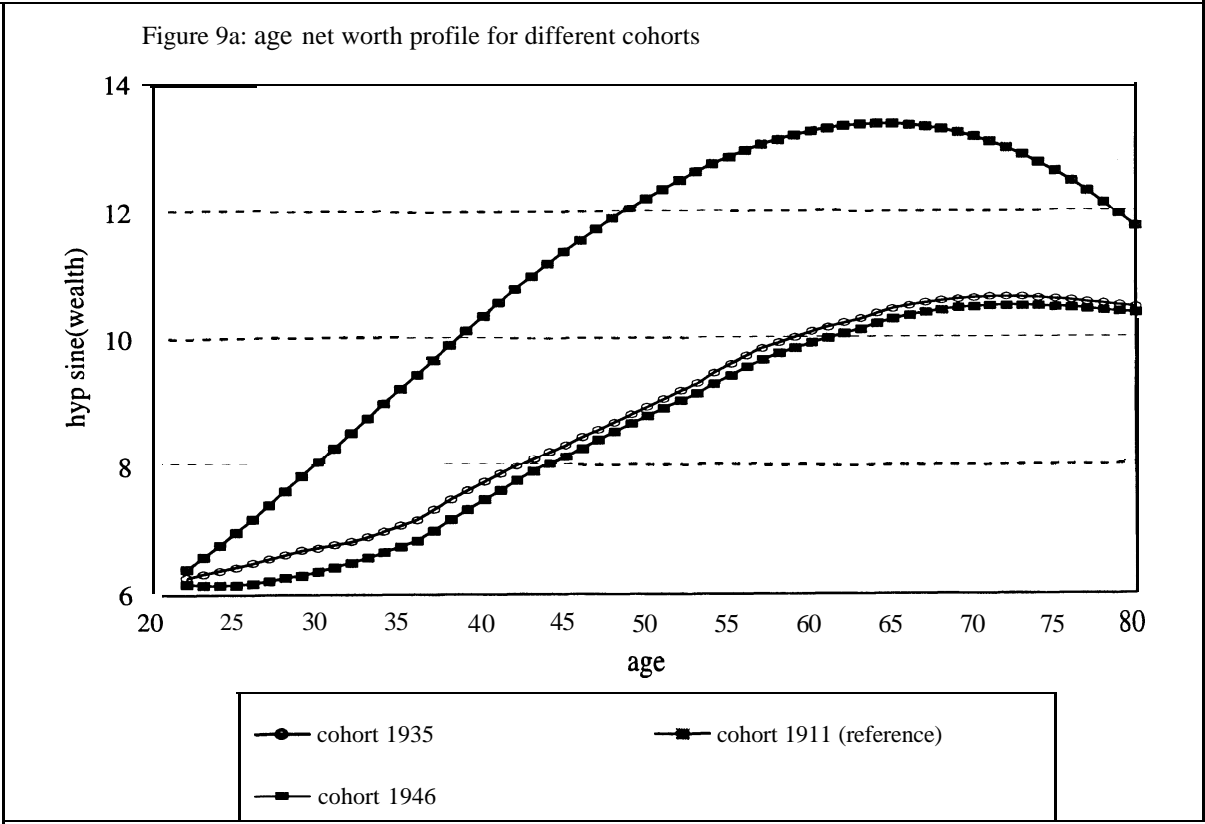


Figure 10a: The relative change in net worth (and 95% confidence bands) across age of the generation born in 1911

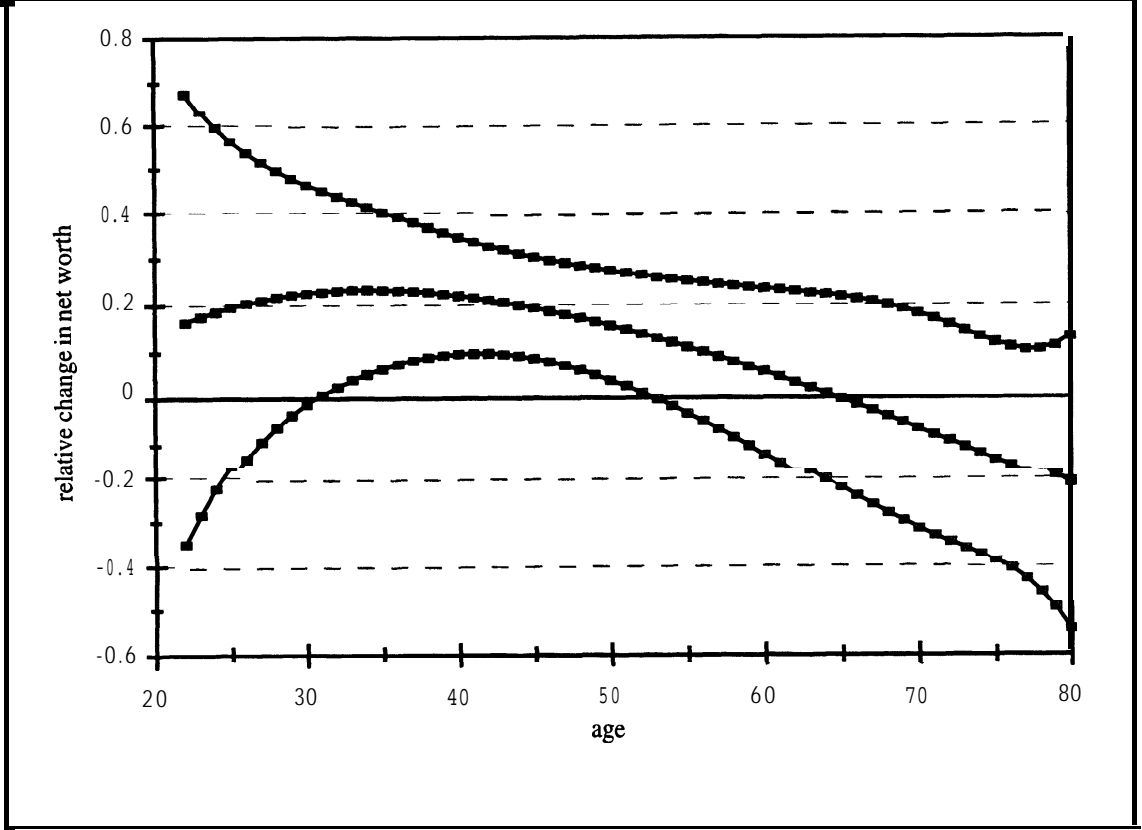


Figure 10b: The relative change in financial wealth (and 95%-confidence bands) across age of the generation born in 1911

